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AGRICULTURAL EXPERIMENT STATION.

ASPARAGUS AND ASPARAGUS RUST IN CALIFORNIA.

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By RALPH E. SMITH.

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ASPARAGUS AND ASPARAGUS RUST IN CALIFORNIA.

By RALPH E. SMITH.

The present bulletin represents primarily a report to certain asparagus growers, canners and dealers of San Francisco, Sacramento, and adjoining territory, who provided a fund of $2,500 for the support of an investigation of the *asparagus rust*, a disease which seriously threatened to destroy or greatly injure their industry. The circumstances under which this investigation was undertaken are interesting and unique. Knowing from its history in the East the destructive nature of the rust, the asparagus interests, on its appearance in this State, appealed to the University of California for aid in suppressing this pest. The University had no funds or men available at the time for such a purpose, and, a bill having failed to pass the Legislature, those most directly interested took the matter into their own hands, and the California Fruit Canners' Association, a leader in the movement, guaranteed to raise and turn over to the University the sum above mentioned if the work should be undertaken. Under these circumstances the writer, having had previous experience in the matter, was called from the Massachusetts Agricultural College to take up the work, which has now extended over two seasons and may be considered as practically completed in its main features. While no sensational discoveries have been made, the difficult problem of protecting the plant from rust may be regarded as solved to a very satisfactory extent, and it is believed that the best growers will continue to produce asparagus successfully and profitably, which could not be done with the rust unchecked.

Acknowledgments.—Acknowledgment for the results achieved is due primarily to all those who aided financially in starting the work. As leaders in this portion of the undertaking must be mentioned Mr. William Boots, Jr., one of the first growers to realize the necessity of action, and Mr. R. I. Bentley, General Manager of the California Fruit Canners' Association, who has been most active in promoting and encouraging the investigation. The money raised came from the growers in the vicinity of Milpitas, Alviso, and San José, those at Sacramento, many of the large growers in the river and island district, the canning company mentioned above, together with the two

other principal asparagus canners, the Hickmott Asparagus Canning Company and the Golden State Asparagus Company, and from subscriptions by a number of commission houses in San Francisco. To these gentlemen the credit belongs of starting and supporting the investigation.

In carrying on the work the writer has been given every assistance by all with whom he has come into contact, and must acknowledge the hearty coöperation of the various growers and canners in the different districts in carrying on practical studies and experiments, furnishing accommodations, transportation, etc., and providing supplies, appliances, labor, and similar items. Experimental work in the field has been carried on at the following places, but the publication of such a list is almost an injustice to many others who were equally ready to assist had they been called upon.

The bulk of the whole work has been performed at the Boots ranch near San José in conjunction with Mr. William Boots, Jr., whose continual coöperation and assistance the writer wishes to fully acknowledge. Messrs. John Meads, George Nicholson, and Fred Cottle of the same district carried on various parts of the work in 1903. Similar work was done at the same time with the Hickmott Asparagus Canning Company at their Bouldin Island establishment, Mr. E. A. Schultz of this company being one of the most active of those interested in the problem. In 1904 new work was carried on at Mr. P. J. Van Löben Sels's ranch at Vorden, where every facility was furnished by the proprietor to make the undertaking a success. Valuable information was also obtained from the practical work carried on by most of the Sacramento and Milpitas growers in testing the methods recommended for trial in preventing the rust. Among these were, Mrs. M. M. Harding, E. Rider, O'Brien Brothers, Jacob Olsen, John Giusto, and C. Girolami of Sacramento, and R. S. Barber, H. H. Cropley, M. Bellew, Henry Abel, and George Murphy of Milpitas. Besides these growers and others already mentioned the writer can not refrain from acknowledging the active interest in the work shown by Messrs. Hodges, Gaum, and A. L. Smith of the California Fruit Canners' Association, Messrs. Robert Hickmott and his associates in the company already mentioned, Capt. E. H. Nielsen and Mr. N. Goetjen of the Golden State Company, Messrs. Jongeneel and Bromage of the Vorden Ranch, Mr. G. Oulton of Twitchell Island, and Mr. J. W. Nelson, now of Hunt Brothers Company. The Southern Pacific Company, by its generous policy in matters of transportation, has also aided materially in the work. Still further mention may be appropriately made of Messrs. Frank Wheeler of Concord, Mass., Wm. Conover of Middletown, N. J., Donner Brothers of Seabrook, S. C., and P. A. Bonvallet of Wichert, Ill., all of

whom have rendered assistance in various ways. To a host of other growers, canners, and handlers of asparagus in many different States the writer is indebted for information and assistance.

During the two seasons covered by the investigation most of the writer's time has been spent in the various asparagus districts, and he has also had opportunity to supplement previous observations by trips through the Eastern asparagus centers in 1903 and 1904.

Two publications have been issued in connection with the work: Circular No. 9 of this Station, "Report on Asparagus Rust Investigation," and a more technical article in the Botanical Gazette, July 1904, on "The Water Relation of Puccinia Asparagi."

Results Achieved.—The most valuable results achieved, as will appear in the following discussion, may be briefly stated as follows:

The discovery of climatic conditions peculiarly favorable to rust suppression in the greatest asparagus-producing region of the State.

The determination of the best cultural and other means for taking advantage of such conditions.

Other cultural methods found effective in keeping down the disease.

A test of many methods of treatment by spraying and similar operations.

The discovery of the peculiar effectiveness of *sulfur,* when properly applied, in treating the rust in California.

Determination of the best methods, time, etc., for applying sulfur and the development of special appliances and machinery for the purpose.

The discovery and study of an active parasite upon the rust fungus.

The determination of comparative resistance to the rust of the various varieties of asparagus, importation of varieties not obtainable in this country, and the commencement of breeding experiments for the production of new varieties, rust-resistant and otherwise desirable.

Study of the problem under the local conditions of all parts of the principal asparagus-producing region, and adaptation of the results to each locality.

ASPARAGUS IN CALIFORNIA.

The extent and importance of the asparagus industry in California is little realized outside the circles of those connected with the business. The crop is looked upon by many as a pleasant luxury, grown in certain suitable localities for supplying the city markets in spring. The fact is that the city markets take but a small portion of the asparagus produced in the State, and, to a large extent, the poorer quality at that. The business proper has quite a different object than supplying such markets.

Asparagus has been produced in California for many years. A small field is still in existence in Sacramento which is known to have been planted in 1852, while in the vicinity of San José the crop was also grown at an early period. In its present condition the business is of

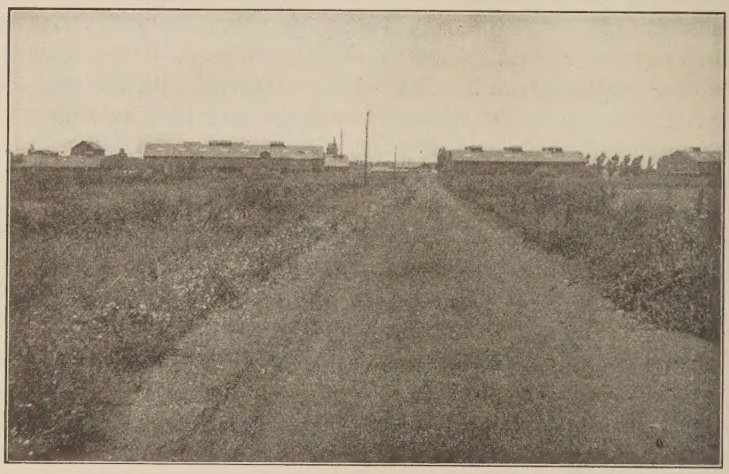

FIG. 1. Cannery No. 2. Hickmott Asparagus Canning Co., Bouldin Island.

recent origin, mostly the growth of less than ten years, and has come into existence through the development of asparagus canning and the rapidly increasing demand for the product. Canning of asparagus on a commercial basis has been practiced for only a few years in Cali-

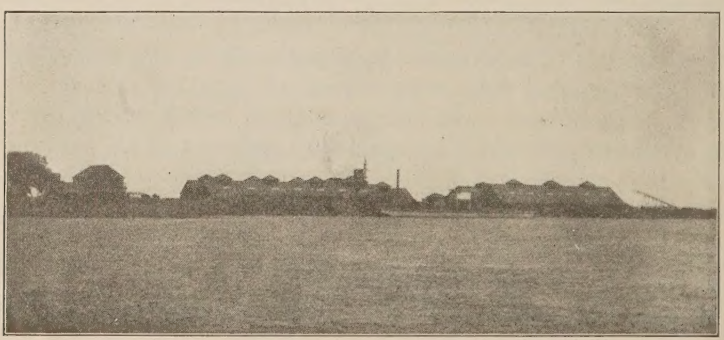

FIG. 2, Cannery No. 3. Hickmott Company, Bouldin Island.

fornia. Considerable difficulty was experienced at first in putting up the vegetable with uniform success, and as the market for any considerable amount of canned asparagus was entirely undeveloped in the early history of the business, conditions, even as late as ten years

ago, gave little indication of the development of any such industry as now exists. The business, when once established, proving to be very profitable, both to producer and canner,

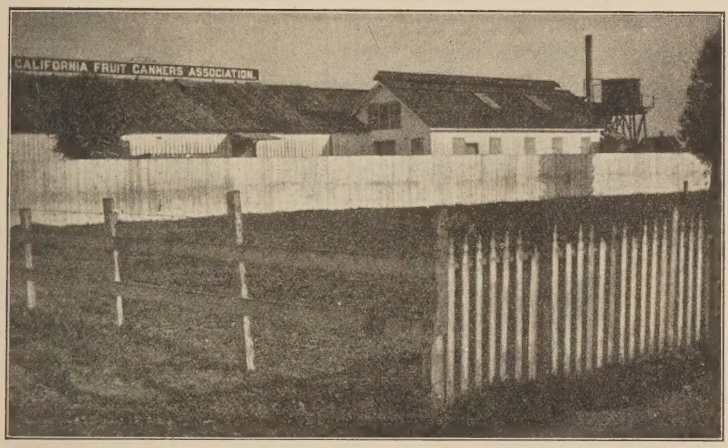

FIG. 3. Milpitas cannery. California Fruit Canners' Association.
Enlarged in 1905.

large plantings of the vegetable were made, and up to 1902 the acreage increased enormously. Meantime the rust disease had crippled the canning of asparagus in other parts of the country, located principally

FIG. 4. Sacramento cannery. California Fruit Canners' Association.
Rebuilt in 1905.

on Long Island and in New Jersey, and with the greatly increased demand for canned asparagus the planting of the crop enjoyed quite a boom in California. This new planting took place principally in the

delta country between Sacramento, Stockton and Port Costa, at the junction of the Sacramento and San Joaquin rivers, where the peaty and sedimentary soils, after reclamation by levees and pump drainage, proved especially suited for the production of canning asparagus. In 1903 there was nearly 6,000 acres of asparagus in this section. The leader in this development was the Hickmott Asparagus Canning Company, and to Mr. Robert Hickmott belongs much of the credit for the present popularity of canned asparagus. With great confidence as to the future of the business he went ahead at Bouldin Island, contracting for the planting of an enormous acreage and building canneries to handle the product. This company's two large canneries on the island, used exclusively for asparagus, are shown in Figs. 1 and 2. The

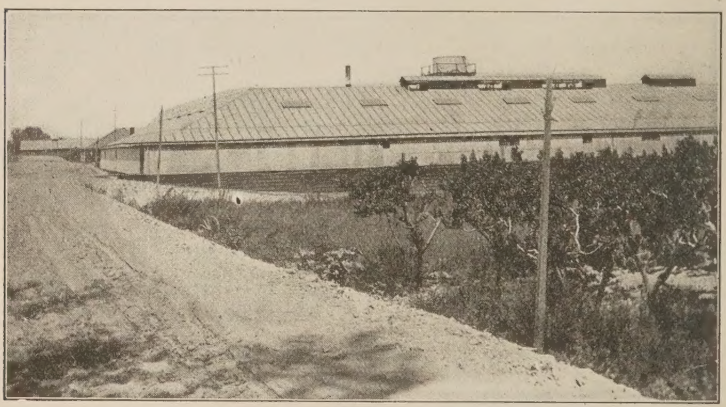

FIG. 5. Vorden cannery. California Fruit Canners' Association.

flooding of Bouldin Island in the spring of 1904 and consequent crippling of the business was a distinct calamity to California.

Other canners were also early in the asparagus field and the California Fruit Canners' Association, after its organization, began to build up an asparagus business which is rapidly enlarging as the later planted fields come into bearing. Their cannery at Milpitas (Fig. 3), established originally by the Oakland Preserving Company, handles most of the product of that district, which is an old asparagus-growing section, while that at Sacramento (Fig. 4) was one of the first to pack asparagus and takes almost all of the vegetable produced by the growers on the outskirts of that city. They have further an asparagus cannery at Vorden, on the great Van Löben Sels estate (Fig. 5), and likewise pack more or less asparagus in their San Francisco canneries.

The Golden State Asparagus Company is the third of the important

asparagus packers. Their new cannery at Andrus Island (Fig. 6) is well equipped for the business and situated in the midst of their large and increasing asparagus fields. The Goetjen and Metsen fields on Grand Island are also under the control of this company.

FIG. 6. Andrus Island cannery. Golden State Asparagus Company.

Hunt Brothers, large fruit and vegetable canners, have recently built a small asparagus cannery at Antioch (Fig. 7) to pack aspara-

FIG. 7. Hunt Bros.' asparagus cannery. Antioch.

gus from various points in the island section which they have contracted. An asparagus cannery has also been built at the Sylvester & Graves place below Stockton.

Other companies can more or less asparagus from the city markets,

but these comprise all those who make a specialty of the business, packing directly from the fields. The process is clean and appetizing and the product healthful and delicious, being immeasurably superior to fresh asparagus bought in the market and cooked at home.

Asparagus is grown in gardens all over the State and commercially, in a small way, near most of the larger cities. In Orange County a number of growers are engaged in producing fresh asparagus for the early Chicago market. The warmer portions of the State do not seem as favorable to the crop, and the fine large white asparagus of the canning sections is not seen in the south. Asparagus has recently been planted in the Coachella Desert country in the Salton Basin, and hopes are entertained of the development of a considerable industry in that region.

There are now about 7,000 acres of asparagus in California, including the flooded islands, located mostly in the river, Milpitas, and Sacramento sections. Of this, about 1,500 acres consists of young beds which will be cut for the first time in 1905. No extensive new planting has been done since 1902, but for 1905 the planting of from 500 to 1,000 acres is contemplated. The lower figure is probably nearest the amount which will be actually put out.

THE ASPARAGUS PLANT.

Asparagus *(Asparagus officinalis)* is a plant of the lily family, a native of the old world, which has been cultivated as a vegetable from the earliest times for its tender shoots produced in spring. It was grown in Massachusetts as early as the seventeenth century, and has ever been a popular vegetable all over the country. The plant consists of a fleshy, branching crown, rootstock, or rhizome, numerous long, tough roots, and a number of shoots or stalks above ground (Fig. 8). The plant is perennial, sending up shoots year after year almost indefinitely if not killed or injured in any way, and is difficult to eradicate from the soil. The roots are long, extending for many feet in depth and forming a solid mass in old beds. The crowns grow and branch extensively in all directions, with the new growth mostly on top of the old, so that the roots tend to come to the surface. At the ends and on the sides of the crowns are produced the buds from which come the shoots that grow up into the air. When these shoots are cut, new buds keep coming out and the plants show remarkable vitality in sending up stalk after stalk through the long asparagus-cutting season, when no growth above ground is permitted. This can not continue indefinitely, however, but tops must be allowed to grow up in time to mature and store up new energy in the plant for next

year. Too long a cutting season weakens the plant and hastens the time when it ceases to produce profitably. Weakness shows first in the size of the stalks, for they become smaller when lacking vitality.

When allowed to grow the stalks elongate very rapidly, putting out side branches and small needle-like leaves and forming a thick, bushy top with a height of from three to seven feet (Fig. 12, page 17). Small greenish-yellow blossoms appear on the branches at about the fourth week of the growth, from which berries develop, which, when

FIG. 8. Asparagus root and shoots.

ripe, are bright red in color, juicy, and contain the black seeds. The plants are dicœcious; that is, male and female, the latter alone bearing seed.

CULTURE OF ASPARAGUS.

Asparagus is grown from seed, planted quite thick in close rows in a nursery bed, and the roots then transplanted to the permanent field. The seed is thoroughly soaked and warmed before planting, to insure quick germination. The roots may be transplanted when one, two, or three years old, but in California are most satisfactory at one year, if well grown. They are dug in the winter after the tops die down, allowed to dry if kept long, and planted as early as possible in

the spring. The permanent bed must be in a soil specially suited to asparagus if it is to succeed, particularly for canning-asparagus, which requires a large production of high quality for profit. The typical California asparagus soils are of two classes: the sediment soils, as at Sacramento and Milpitas, composed of fine, sedimentary river deposits, and the island peat soils, composed in places, on the San Joaquin side particularly, of almost pure organic matter; or again, on the Sacramento, of mixtures of peat and sediment or clay in various proportions. The structure of the island soil formations varies considerably, some having pure peat to a depth of thirty feet or more, as at Bouldin Island, others with underlying strata of clay and sediment at various depths. The soil must be fertile, naturally moist or capable of irrigation, well drained, and not forming hard lumps. The last is especially essential in growing straight stalks for canning.

The distance between the rows varies in different sections. At Sacramento, where new soil and manure are applied every year, they are five feet apart. This is very close, except for small fields on valuable land. At Milpitas seven feet is the usual distance, while in the great island plantations nine or even ten feet is a common distance. In this soft soil the crowns spread very rapidly and close planting makes a short-lived bed, the asparagus soon becoming crowded and running down in size. The distance between plants varies in the same way. Nine feet by two is advisable in the island section, and about seven by one and a half on sediment soil. Where quick returns are more desired than long life, as on leased lands, closer planting is advisable, up to four feet by one. This will give a large yield for a few years, but will soon run out.

The roots are planted in a deep furrow which is gradually filled as the plants grow. In countries where manuring is customary a trench is made and filled at the bottom with manure, over which the roots are planted. The plants should be allowed to grow two years before any cutting is done. In the third year cutting should stop early in the season, not continuing over six weeks. During these first two years it is customary to grow some annual crop between the rows. This is useful in keeping the ground cultivated so long as the asparagus plants do not suffer. Careless tenants sometimes injure the latter more than the value of the temporary crop. Clean cultivation and no breaking down of the asparagus must be insisted on. Crops thus commonly grown are beans, potatoes, and onions, of which the first is least objectionable.

Asparagus may be grown either green or white, according as the shoots are allowed to grow several inches above ground before being cut, or are cut as soon as the top breaks the surface. In the latter method

by which all the canning asparagus is grown, the dirt is ridged up high on the rows in order to produce long, tender, white stalks (Fig. 9). These ridges are put up in early spring as soon as the ground can be worked, and kept up through the cutting season (Fig. 10). They are made by plows, disks, hand implements, and various special machines devised by different growers. Much the best of these is the modified disk cultivator devised by Mr. Boots, and in use by him and others.

The asparagus shoots are cut, as soon as the top appears, by means of a long-handled gouge (Fig. 11), carried out of the field in baskets.

FIG. 9. Section of asparagus row.

washed, trimmed to a uniform length of seven inches, packed in bulk into 60-pound boxes (see cover), a burlap and slat cover tacked on, and the boxes then sent to the cannery or market. In the East asparagus is sold in bunches—1¼ pounds in Boston, with a wholesale unit of a three-dozen-bunch box, while New York takes a 2½-pound bunch, sold at wholesale by the dozen. Boston requires green asparagus; New York and most other markets, white. Bunching is not practiced to any extent in California, except for the earliest asparagus which is shipped East in the fresh condition.

Cutting begins somewhat in February, but is quite light until late in March, when the canneries open. The season varies in length, with

FIG. 10. Asparagus field in cutting season.

a tendency for the canneries to run longer each year on account of the demand for canned asparagus. They close during the latter part

FIG. 11. Chinamen cutting asparagus.

of June and early in July, making a season of from ninety to one hundred days.

The yield of asparagus in California is large, compared with East-

ern districts. This is on account of the long cutting and growing season and the deep, fertile soil; 5,000 pounds of merchantable aspar-

FIG. 12. Asparagus plant, showing continual development of new shoots.

agus per acre is no more than a fair average for large plantations, estimating producing fields of all ages together, while in good fields of prime age 7,000 or 8,000 pounds are often produced without any

FIG. 13. Field of asparagus in fall.

fertilization. By reason of these large yields and the excellent quality of the product, no other portion of the country can compete with California in canning asparagus.

After the cutting season the rows are plowed, disked, or harrowed down as flat as possible, and the shoots at once grow up and produce the thick tops (Figs. 12 and 13). These remain until late in November or December, when they become mature and are killed by frost. Then the old tops are cut, the stubble chopped out with hoes, the fields plowed, harrowed, and prepared for the new crop. The beds should be cultivated and kept clean all through the summer, though too often this is neglected after the tops grow up.

In the majority of cases asparagus is grown in California on a share system with Chinese tenants, the owner furnishing land, utensils, horses, and all necessities for handling the crop, while the Chinaman supplies the labor and receives fifty or sixty per cent of the product.

THE ASPARAGUS RUST.

Asparagus rust is a disease of the asparagus plant. In Europe it has been known for at least a century, and is as old, no doubt, as the history of the plant itself as a cultivated vegetable. No great importance, however, attaches itself ordinarily to the rust in the old world, as it is neither abundant nor destructive, although the writer has recently learned of a considerable outbreak in the Brunswick region during the past year or two. Further information in regard to this case would be of much interest, and perhaps shed more light on the remarkably sudden and destructive occurrence of the disease in this country. As known at present the rust started in epidemic form in the North Atlantic States during the fall of 1896. Dr. B. D. Halsted[1] of the New Jersey Experiment Station was the first to call public attention to the matter at that time, and states "after a full correspondence with botanists, horticulturists, and asparagus-growers, that the outbreak of the rust seemed to be limited in that year (1896) to New England, Long Island, New Jersey and Delaware." In 1897 the rust was much worse in the regions previously affected and extended to the South Carolina fields about Charleston, spreading to the south and west. In the asparagus centers of Massachusetts, Rhode Island, Long Island, New Jersey, Delaware, Maryland, and the other asparagus-growing regions in the Atlantic States, the green tops were completely killed in July, creating a condition which certainly had not occurred before. In the meantime, Professor Halsted[2] states from his correspondence with persons in every State and Territory, that "the vast

[1]Bulletin 129, N. J. Agr. Expt. Sta., 1898.
[2]Annual Reports of N. J. Agr. Expt. Sta., 1897-1903.

interior and the western part of the United States seem as yet free from rust'' (1897). In 1898 the disease was less abundant in some of the first affected sections, but was found for the first time as far west as Michigan. Rust was again very prevalent in the East in 1899, and was found in Illinois, Ohio, and Kansas. In 1900 the Atlantic States were again badly affected, while its regular westward progress brought the rust into the Dakotas, Nebraska, and Texas, or, in other words, out to the semi-arid States and Territories east of California, which have no asparagus fields of any extent.

In spreading from Massachusetts to Texas during these five years the rust usually made its first appearance in each State in the largest asparagus sections, as would be expected. From these places smaller beds soon became affected, so that, on the whole, the progress of the disease was remarkably uniform from east to west across the country. In 1902 and 1903 the rust was much less abundant in the Eastern States, for reasons which will be discussed hereafter, while in 1904, although somewhat more prevalent, the attack occurred later in the season and little damage is to be apprehended. After the first few years of the epidemic most of the older beds in the Atlantic States were entirely destroyed, the canning industry was practically abandoned, prices became about double what they had previously been, new varieties came into use, and an entire readjustment of the asparagus industry took place.

It is idle to speculate on the origin of this epidemic and remarkable spread of asparagus rust in the United States as just described. That the rust existed in eastern Massachusetts and Long Island previous to 1896 many growers in those sections feel convinced. That it never occurred before in any such destructive manner is morally certain. Farther west, in the Central States, there are not lacking those who claim to have seen asparagus rust long before the present outbreak, and some whose observations are worthy of consideration. The situation in California, as will be shown, is similar, and on the whole the writer is not prepared to deny that asparagus rust had existed in this country to a limited and unimportant extent previous to 1896. That an entirely new and distinct outbreak, of unparalleled severity, started in that year and spread across the country can not be doubted. The idea entertained by some that the rust, previously overlooked, simply came to be noticed at this time on account of the unusual attention attracted by it, can not be seriously considered. Such damage as has been caused in recent years could not fail to have attracted attention had it occurred previously, and the condition of the plants would have been noticed previous to the years mentioned above by those who were looking especially for rust in the various States.

THE RUST IN CALIFORNIA.

The same uncertainty attends the history of asparagus rust in California as in other sections of the country. While a distinct epidemic has occurred during the past three or four years, the progress of which can be easily traced, we can by no means be certain that this is the beginning of the matter. Of particular interest is the fact that in the year 1880, the late Dr. Harkness published, in a list of fungi of the Pacific Coast, the name *Puccinia asparagi*, the asparagus rust, from Sacramento. This is the only published mention of the rust in the United States previous to 1896. No specimen was preserved and a mistake may have been made, though the fungus is easily identified. To the best and most observant growers in the State the disease was entirely new at its recent appearance, and we may feel sure that previous to 1901 there was no rust in the large asparagus-growing sections of the State in any such form as has occurred since that time. It is still the writer's conclusion, based upon various facts and observations by himself and others, that asparagus rust may have occurred in California, to a very limited and unimportant extent, for a number of years. There is indeed some evidence to show that a slight epidemic occurred in one section of the State some forty years ago, though this again is uncertain.

The present outbreak appears to have started in southern California as early at least as 1900 or 1901, some placing the date even earlier. The growers first noticed it in 1901. No report of the matter was made until 1902, when the rust was also present on all the fields in the Milpitas district, near San José. From the growers' observations there was rust in the latter section on some of the beds in 1901, and probably that year for the first time. Thus it is seen that the epidemic in California connects in time with that coming from the East, which reached Texas in 1900.

In 1902 the California State Board of Horticulture passed a resolution prohibiting the importation of asparagus roots or seeds into the State, but as the rust was already present this regulation was of no avail.

At Bouldin Island Mr. E. A. Schultz, a most careful observer, kept close watch for rust, and first detected it in October, 1902. Examining the surrounding region he found the disease present in a scattering manner as far north as Grand Island.

Since the taking-up of the work by the writer in the spring of 1903, the matter has been closely followed and definite statements can be made. In the fall of that year the rust outbreak occurred for the first time at Vorden and Sacramento, thus including the most northern

of the large asparagus sections. Small beds at Marysville, Chico, and other northern points were not affected in 1903 or 1904. Santa Barbara, Fresno, and other intermediate points in the State were found infested in 1903, and no doubt the rust was there before then. The spread of the disease is thus seen to have been from south to north in the State; southern California 1901 or sooner, Milpitas 1901, Bouldin Island and surrounding section up to Grand Island 1902, Vorden and Sacramento 1903. As in other States the spread has not been entirely regular, reaching forward into the larger asparagus sections at first, then extending to the smaller beds, but these dates represent accurately the main advance of the rust epidemic in California.

With all the uncertainties and doubtful features connected with the origin and spread of the disease, these facts are positive and indisputable. The asparagus plantations of the United States were healthy and free from any pronounced symptoms of rust up to 1896. The disastrous outbreak of disease started in August of that year from the Atlantic coast, and finally reached Sacramento, California, in August, 1903, affecting every important asparagus-growing section in the country in the general order outlined above. Whether or not the rust existed here before, and wherever it may have been, this was certainly a new and distinct occurrence, having no connection with previous conditions and presenting a remarkable example of the spread of a plant disease, affecting a not over-common crop, over the entire country wherever the crop is grown at all extensively, within a period of seven years.

NATURE OF THE RUST.

Rust is a disease which does not affect directly the asparagus which is cut for market, but makes its appearance only upon the green tops which grow up after cutting has ceased. By killing these tops, which should grow and store up strength in the roots for the next year's crop, the disease weakens the plant, diminishes the yield and quality of the product, and if severe enough kills the plant entirely. The trouble is ordinarily first noticed by the careful observer, by the presence of red spots in the thick mass of green tops. This may occur at any time after the tops branch, blossom, and "feather" out, depending, in California, upon weather conditions and the nearness of rust infection. In the worst affected places rust appears as soon as the tops are grown, while in the open island country it may not come on until October. The red spots may be as large as one's hand when first noticed. If examined more closely it will be seen that the red color is due to a condition shown in Fig. 19 on page 29, the stems and needles being covered with little blisters from which a reddish "rusty"

powder escapes. If one is familiar with the disease and searches carefully, he may detect it even before the red spots are large enough to be evident. He will find at the very first single blisters here and there, producing the red powder, as in Fig. 14. About these the larger rusty areas develop, and, spreading rapidly if conditions are favorable, the isolated spot soon extends up and down the row, across to adjoining rows, connects with other similar spots, and with great rapidity the whole field is soon red and rusty. On passing through the tops one's hands and clothing become colored by the dark red powder from the innumerable rust blisters on every twig and needle, and a cloud of

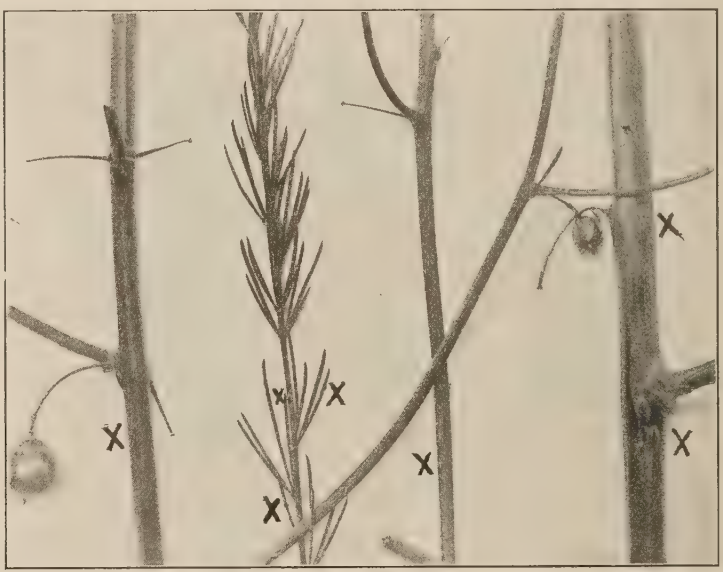

FIG. 14. First appearance of Uredo (red) Rust on twigs and needles *(X, X)*.

the same dust scatters into the air. Soon the red tops begin to turn to a bright yellow, giving an appearance of premature maturity. The needles fall to the ground, the yellow color is lost, and now nothing remains but the bare, dead stalks, still covered by rust pustules, which become black in color and no longer dusty (Fig. 23, page 35). This is the final stage, and the sight of his fields dead and black in August or September, when formerly they presented a mass of rich green foliage dotted with the coral-red berries, is a most distressing one to the asparagus-grower.

Still another form of rust may be seen in the early part of the season during the cutting season, upon asparagus which is allowed to grow up at that time. This likewise appears as a breaking out on

the surface of the plant, but more upon the main stem and branches than upon the needles. There first appear oval-shaped patches of a lighter green than the normal. From these little round pustules develop in concentric lines, each pustule opening into a little cup from which scatters a powder dust. This form occurs only early in the season and disappears in June or July, giving place to the single red and black pustules described above. All three forms may often be seen together on stalks which grew up in the spring, the red and black forms breaking out around the edges of the light green ovals. These three forms are called respectively the *spring, summer* or *red,* and *fall* or *black* rust, and are to be seen in abundance at the proper season in any of our asparagus-growing districts. They all represent one and the same disease in its different variations. The rust is easy to determine and no one can mistake its symptoms when once familiar with them.

CAUSE OF THE RUST.

The cause of the rust is well known, having been described by the French botanist de Candolle as early as 1805, a century ago. The disease is produced by a parasitic fungus named by de Candolle *Puccinia asparagi.* This fungus is one of the true rusts, a very characteristic type of parasites, with such other examples as the grain rust, rusts of various grasses, carnation rust, prune and peach rust, and many others of common occurrence. These rusts are vegetable in their nature, plants in fact, but strict parasites, being able to exist only upon the particular plants which they affect.

The visible part of the asparagus rust-fungus is represented by the blisters, pustules, etc., which break out on the surface of the plant, and the dusty powder which comes from these eruptions. That this is a definite fungus, a true parasitic plant, can easily be seen with the microscope. That it is the cause of the trouble with the asparagus may be considered self-evident, but can easily be demonstrated by shaking a rusty stalk in the dusty condition over unaffected tops when wet with dew; or the experiment may be performed more carefully by placing a small quantity of the red dust in a known spot on a healthy plant, where it will be moist and shaded for a few hours or over night. From such infections the disease will soon appear.

This red dust which gives the rusty appearance, the black pustules of the fall rust, and the dusty powder which comes from the little cups in the spring rust, all represent the *spores* of the fungus, and, although the dust is very fine, each particle is a single spore capable of starting the rust anew. Beneath each pustule of rust on the surface the plant tissue is permeated by a mass of fine filament threads

which absorb nourishment for the parasite and thereby injure the plant. Each needle becomes full of the fungous growth, the surface tissues of the stem are likewise affected, and all the green parts of the plant become thoroughly infested with the vegetative portion or *mycelium* of the fungus. The spores are then produced and pushed out through the surface. These, then, are the two parts of the fungus; the *mycelium* or inside growth, invisible to the sight, and the *spores*, three different forms, which break out on the surface.

THE MYCELIUM.

The filaments of the rust fungus have no peculiar structure, but are long, narrow, and extensively branched, ramifying

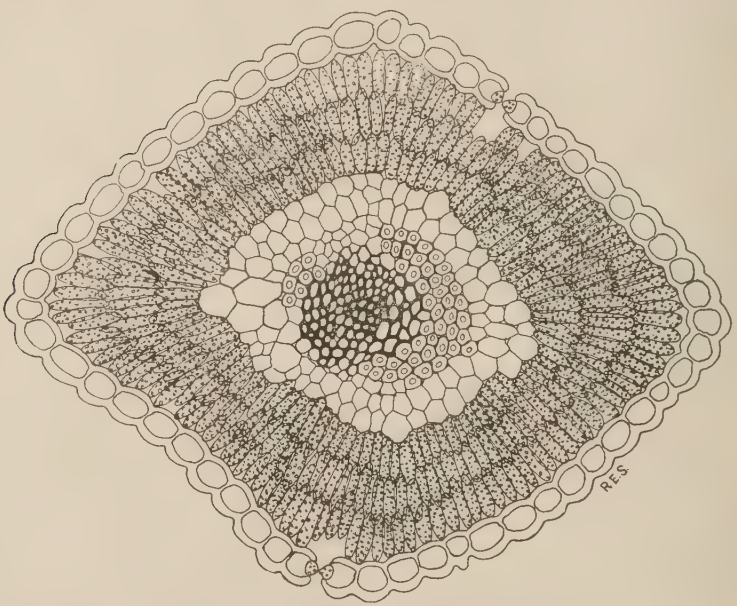

FIG. 15. Cross-section of asparagus needle.

between the cells of the green parts of the plant, but extending only very slightly into the more solid portions. Fig. 15 represents the structure of an asparagus needle or small branch, in cross-section. On the outside appears the epidermis, a single layer of thick-walled cells. Next, a three-cell layer of delicate tissue. These cells contain the green chlorophyll and give the plant its color. In the center is a fibrous portion. In the larger stems the fibrous part becomes increased, while the green is still a thin surface tissue. Fig. 16 represents one of the green cells much more enlarged. In it are seen the numerous large chlorophyll granules which have the green color.

Fig. 16 also shows more of these cells with their contents affected by the rust-fungus filaments, which are represented between them. These filaments run all through the green tissue in this way. They pass between rather than into the cells, forcing them apart, but at numerous points the *haustoria* (*a*, *a*, *a*, of the figure) develop, which appress themselves closely to the sides of the cells, making an indentation and perhaps breaking through into the interior in some cases. These are the absorptive organs which take up nourishment for the fungus out of the plant cells and disastrously affect the latter. The mycelium, starting first as shown in Fig. 22 on page 31 and explained later, spreads through the green cell tissue in all directions in the man-

Fig. 16. Effect of rust mycelium on plant cells.

ner shown in the figures, and finally, gathering into a thick mass at certain points just under the epidermis, produces and pushes out through the surface a spore pustule, as in Figs. 20 and 24 on pages 30 and 36. In each of these illustrations is seen the aggregation of mycelium just under the spore cluster. In the figure of the spring rust (Fig. 18, page 28) will be seen how all the cells are crowded apart by the fungous growth between them, and this produces the light-colored oval spot in which the spore cups develop.

Effect of the Rust Mycelium on the Cells and Tissues.—The green cell tissue of plants is, in a physiological sense, most important, having functions much beyond that of simply giving color to the leaves and other green parts. Structurally, as we have seen, the green matter is

in the form of corpuscles, contained in large, thin-sided cells just under the epidermis. In the asparagus leaves or needles it extends practically to the center, but on the stem and branches forms a thin surface layer, which may be readily seen and scraped away after peeling off the delicate, colorless epidermis on the surface. It is the function of this green tissue to carry on a process by which plant-food is formed out of the raw materials provided by nature. The plant takes in water from the soil and carbonic acid gas from the air. These substances are decomposed by the action of the green corpuscles during sunlight and reunited into starch, sugar, and similar carbohydrates. This is the fundamental process in plant nutrition and precedes all other digestive operations. The importance of the chloroplasts (chlorophyll grains) is, therefore, apparent.

Fig. 16 is intended to represent in detail the effect of the rust mycelium upon the green tissue which it inhabits. In a general way it may be said that the filaments absorb food for the fungus out of that assimilated by the plant, and thus weaken the latter to that extent, but the effect is much more than this. Comparing the figures in order from left to right, the pronounced effect upon the chloroplasts will be observed. In the normal cell they are plump, rounded, and distributed uniformly about the circumference of the cell, free from one another. A rust filament coming into contact with the cell does not merely absorb nutritive substances from it. The chloroplasts immediately begin to shrivel, collapse, draw together in the interior of the cell, and indicate by their appearance that they are dead and functionless. The mass runs together, then by continued shrinking divides usually into three portions, as shown. The cell is now dead, and as the whole leaf, the whole plant, and the whole field become similarly affected, the change from green to red, yellow, and finally brown, or the color of dead tops, gradually takes place. The sudden death of the tops and weakening of the plant in vitality are explained by the active destruction of its green tissue and most vital part, rather than by the loss of the amount of nutriment which the parasite takes to itself.

The exact effect of the mycelium upon the chloroplasts, and its cause, present one of the interesting and important problems of plant pathology. Here is the critical point in the phenomena of parasitism. A filament, coming into contact with an uninjured cell, sends out *haustoria*, which penetrate the cell only slightly, if at all, and immediately the chloroplasts begin to react as briefly described above. Apparently a soluble substance, poisonous or enzymatic, is excreted, to bring about this effect. The question calls to mind further the various degrees and rapidity of disintegration and destruction produced in this way by other rusts, some living almost as in symbiosis with their hosts, or at least producing little damage for a long period, some causing irritation, structural changes, and abnormalities, but not premature death, some gradually killing the plant or affected part, but very few so rapidly and generally destructive as the asparagus rust.

Going back to infection by the spore (Figs. 21 and 22 on page 31), it is again of interest to recall the phenomena of monoxeny, or limitation of certain parasites to

single host species, polyoxeny, the heteroecious rusts, and similar features of parasitism. Structural peculiarities, both in host and parasite, must be considered as exerting important influences, but the reaction between germ-tube or mycelium of the parasite on the one hand, and the cell contents of the host on the other, be it chemical, physical, or vital, *is* parasitism, and the power to influence the delicate adjustment upon which this reaction hinges would carry with it infinite possibilities in the treatment of pathological problems.

SPORE FORMS OF *PUCCINIA ASPARAGI.*

Having described the mycelium of the fungus which flourishes in the tissues of the affected plant, we may now consider the various spore forms already alluded to:

Spring Rust, or *Æcidium* Stage.

The spring rust form of the parasite may be observed abundantly in California at almost any place where rust occurred the year before and asparagus plants are allowed to grow up without being cut. It is most commonly seen on volunteer plants, young beds not cut, and old abandoned fields. In such places it usually appears upon the first stalks which come up, but is most abundant in April and May. Spring rust is not rare in March and has been found by the writer even in February on early stalks. Later than June it does not develop much in this climate, but passes into the other stages. The oval, lighter-green patches on the stems and branches which characterize this form of rust, are shown in Fig. 17. The single larger pustules are the red rust, but the oval areas of small pustules represent the *aecidia,* or spring rust. The light-colored ovals are simply places where the inner tissue is full of mycelium, ready to produce spores. Climatic or other influences bring about the development of the different kinds of spores at different seasons. The small pustules on the æcidial patches push up from the inside and finally break open into little cups, easily visible with an ordinary magnifier. In these cups are the spores, small, round particles of living matter, each capable of sprouting and reproducing the fungus under favorable conditions. These æcidial spores are produced in chains, coming up from the mass of mycelium at the base of the cup and breaking up into single spores at the outside. Fig. 18 represents a section through an æcidial spot, the cup at the left beginning to push up the epidermis, but not yet open, while the other has opened and is scattering its spores. The plant cells are pushed apart by the mass of filaments which fill in solidly between them.

Red Rust, or *Uredo* Stage.

The rust which appears on asparagus fields in summer after the tops grow up is quite different in appearance from the spring form. This uredo stage begins to show itself quite early, along with the spring

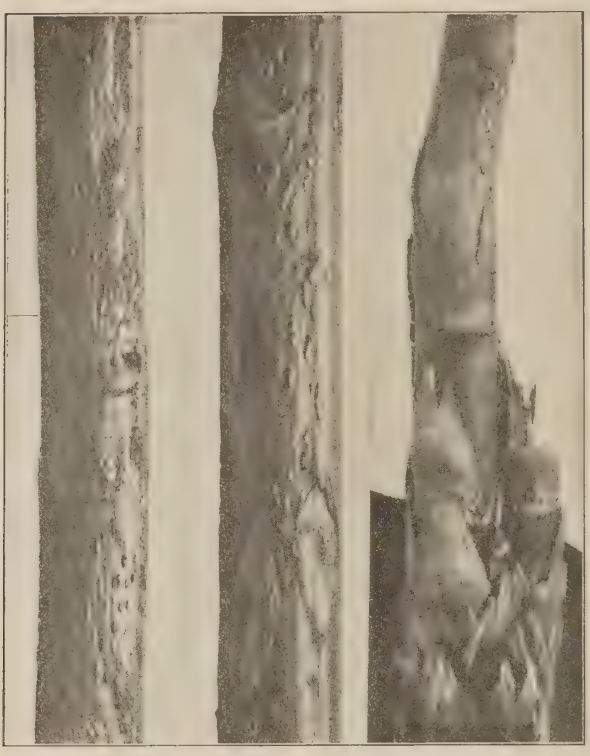

FIG. 17. Spring Rust *(Æcidia)* on asparagus stalks. Stalk at right shows first infection at surface of the ground.

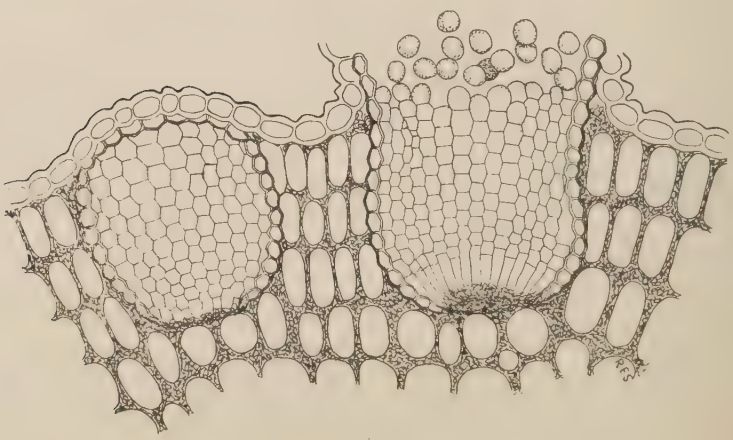

FIG. 18. Cross-section of Æcidial stage or Spring Rust.

rust, as in Fig. 17. It breaks out in single pustules, pushing out through the epidermis and discharging the red rusty spore dust very profusely. In fields badly affected in July or August every branch and needle is covered with the rust pustules of this stage, as in Fig. 19. Fig. 20 shows a section of part of such a pustule, representing the mycelium amongst the cells and spores breaking out through the epidermis very much enlarged. The spores are produced singly, and are seen in various stages of development at the ends of the filaments. These spores have the dark red color which gives the disease its name, and a structure quite similar to that of the æcidial spores.

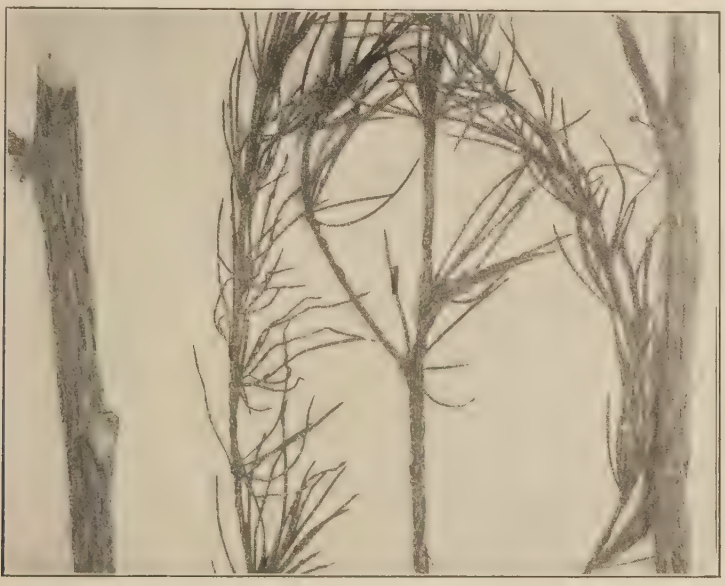

Fig. 19. Uredo (red) Rust.

Germination of Spores and Summer Infection.—The spread of the rust by æcidio- and uredospores is similar and need not be separately described. Carried by the wind or in any other way to the surface of an asparagus plant, the spore, if conditions are favorable, immediately sprouts, sending out a tubular filament, as in Figs. 21 and 22. This grows along on the epidermis, but soon turns downward into the plant, commonly through a breathing pore, as in Fig. 21, but possibly boring directly through in some cases. The writer has never observed the latter case. Passing down through the opening, as seen in cross-section in Fig. 22, the sprout enters the space beneath, extends down between the cells, begins to affect them as previously described, and soon spreads in all directions in the green tissue. This new

mycelium aggregates again into spore pustules, and thus another generation of rust is formed.

Distribution.—Asparagus rust may theoretically be spread in a variety of ways, by any object or agency which passes from infested

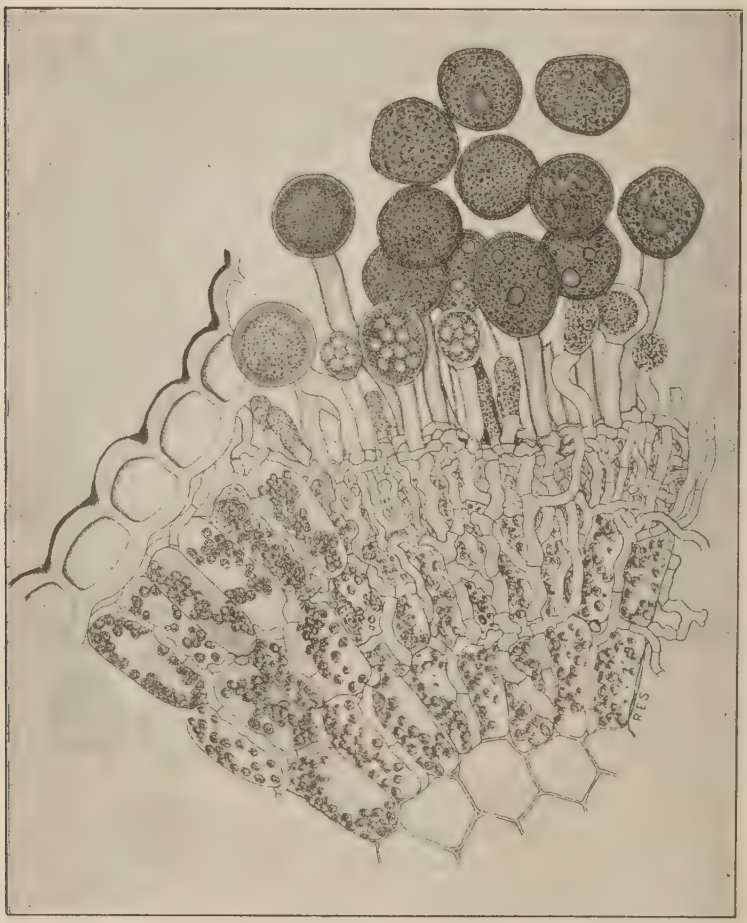

FIG. 20. Cross-section of rust (Uredo) blister.

regions to those not yet affected. When one sees the cloud of dust which arises from rusty plants when disturbed, coloring men's hands and clothing, horses' legs, cultivators, wagon poles and wheels, and anything passing through the field a deep red color, flying away in the wind like smoke, covering the berries which contain the seed, covering and coloring the ground from which roots are dug for sale, and reflects that each minute particle of this dust is a rust spore, it

FIG. 21. Uredospore germinating on surface of plant, and separate spores.

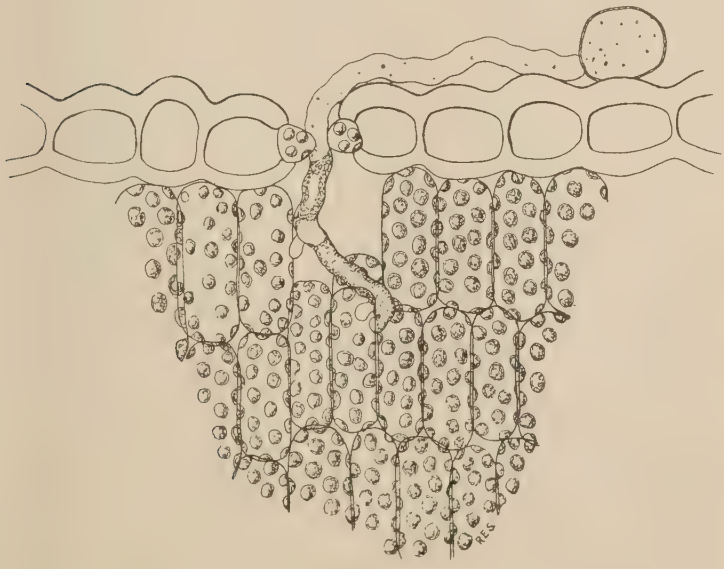

FIG. 22. Cross-section, showing infection from rust spore.

would seem that the spread of the disease must occur in many different ways through the agency of these summer spores. Practically, however, there appears to be but one mode of distribution at all common, which is the distribution of uredospores by the wind. Locally no doubt other agencies come in. Birds, animals, and workmen, passing about the fields, very likely hasten the progress of the parasite somewhat, although without such aid but little difference would be seen in the rate of progress of the disease. That the rust is carried long distances, as from State to State or from the East to California, by means of seeds, roots, or traffic of any sort is extremely doubtful. The progress of the disease has been too regular to be accounted for in this way. Asparagus seed and roots were imported from the East to various parts of California during the entire rust epidemic there, yet the disease came up gradually from south to north at the conclusion of its seven-year steady journey from the Atlantic, with no indication of starting here and there in the State, as would be the case if brought in on roots and seed, and also not appearing any sooner at the places where Eastern importations were planted than at all the other places in the same region. All the indications go to show that the rust has been a most independent traveler, requiring no aid from man to carry it on its way.

In its local distribution by wind the rust shows certain peculiarities in California. Chief of these is the marked tendency of the disease to travel *against* the prevailing wind, from east to west. This is very decided in districts where the rust is abundant. The writer can only account for this by supposing that the prevailing summer west winds are too strong and dry to promote uniform drifting along of the infection from plant to plant. He has often noticed, in the asparagus districts where the condition under discussion is most prominent, that at about sunrise on certain mornings a slow creeping current of mist, close to the ground, drifts in from east to west, being dissipated soon after sunrise by the usual wind springing up from the opposite direction. It seems probable that infection is spread locally, at least, by such slow moisture currents in the air rather than by the strong, dry prevailing winds. In fact, the whole spread of the rust over the country has shown no particular relationship to the latter currents of air, in spite of the fact that distribution has so evidently been through the atmosphere.

Introduction of rust by means of the dusty spring or summer spores clinging to seeds or roots is especially unlikely, although they are so abundant and cover everything in the asparagus field, for two reasons: The short life of these spores, and the fact that they germinate and perish at once when in contact with moisture, whether on asparagus or not. This brings up another subject:

Conditions Affecting Germination and Infection.—Two conditions are necessary to sprout the æcidio- and uredospores; namely, a proper degree of warmth and moisture. The former is a minor consideration, as the ordinary temperature at any time when asparagus is growing is sufficient to germinate rust spores. The moisture relation is of great practical importance, particularly in California. The summer rust spores, like most seeds and other vegetable reproductive bodies, require moisture for germination. When thus supplied they sprout at once, and if the spore has been previously deposited upon an asparagus plant, and no unfavorable conditions exist, infection takes place as has been described. Thus it is readily seen how the mist current drifting along through the asparagus tops, or an ordinary dew, will serve to start infection from any rust spores which may be present. But wherever the dusty spores may be they sprout as soon as they get wet, so that if not on asparagus the delicate germ-tube dries up and perishes as soon as the sun gets high, which is the end of that spore. Countless numbers of spores on the ground, on other plants than asparagus, and wherever they happen to fall, perish in this way. It is for this reason that distribution of rust by the dusty summer spores clinging to seeds and roots is not possible, since with the planting of the same the spores would become moistened, sprout in the ground, if at all, and perish long before the asparagus came up to be infected. The whole process of germination and infection requires only a few hours.

If kept dry the period during which the æcidio- and uredospores retain their germinative power is comparatively short, as shown in Table I.

TABLE I.

SHOWING PERIOD OF VITALITY OF ÆCIDIO- AND UREDOSPORES WHEN KEPT DRY.

SOURCE.	Gathered.	Tested.	Germination.
Æcidiospores.			
Bouldin Island	June 8	June 20	Good
Bouldin Island	June 8	July 2	Very feeble
Bouldin Island	June 8	July 9	Little or none
Bouldin Island	June 8	July 18	None
Milpitas	June 18	June 20	Good
Milpitas	June 18	July 2	A few
Milpitas	June 18	July 9	Apparently none
Milpitas	June 18	July 18	None
Uredospores.			
Milpitas	June 18	June 20	Good
Milpitas	June 18	July 2	Good
Milpitas	June 18	July 9	Good
Milpitas	June 18	July 18	Good
Milpitas	June 18	Sept. 28	None
Bouldin Island	June 8	Sept. 28	None
Riverside	June 26	July 2	Good
Riverside	June 26	July 18	Good
Riverside	June 26	Dec. 12	None

It is seen here that the spring spores will sprout no longer after being kept dry for a month, while the uredospores, though somewhat longer lived, retain their vitality for only three or four months at most. This again precludes wide distribution by such spores on seeds and roots.

The amount of moisture required to sprout the spores is not great. If placed on a dry surface, in a closed moist chamber or glass dish where the air is saturated with moisture, germination soon starts. In a drop of water the spores sprout immediately, as in Fig. 21. The lightest dew is therefore sufficient to start germination. In the field it is necessary that the moisture should remain for at least a few hours in order to give the sprouting filaments time to get down into the inside tissues before the sun dries them up. For this reason a light dew deposited just before sunrise and quickly drying again does not start infection; and for the same reason rust is seen first in the sheltered spots among the tops and wherever the dew lies longest. Rain is less favorable to rust infection than dew, except as it subsequently increases the amount of the latter form of moisture. A heavy rain seems to wash the spores from the plant and often improves its appearance.

The fact that rust spores depend absolutely upon atmospheric moisture to germinate and infect asparagus has been shown by the writer in his previous publications[1] [2] and need not again be elaborated here. The plainest demonstration of this is the green healthy growth of asparagus seen beneath any thick tree which happens to stand in a field, when all the rest of the tops are black and dead. The fact, previously announced by the writer,[1] that "dew is of absolute necessity in infection by the rust" and that "without moisture of this sort no infection can take place, regardless of all other conditions," has been most successfully taken advantage of in California, as previously shown in Circular No. 9, and referred to again later in this work.

Infection naturally follows germination of the spores when they sprout on asparagus plants. We may, therefore, notice here the logical and rational nature of the preventive measures of summer infection outlined in another chapter. First of all, natural parasites may come in to destroy the rust spores. Beyond this the first operation consists in keeping the rust as far away as possible from the fields by allowing no rusty asparagus to grow near by. This keeps the spores out of the field for a longer or shorter period, when no infection can take place. After this resource is exhausted and rust spores begin to blow in from unavoidable sources, imagine an individual case as in Fig. 22. A spore

[1]Circular No. 9, Calif. Expt. Station, 1903.
[2]Botanical Gazette, vol. 38, p. 19, 1904.

falls on an asparagus branch or needle. Dew is deposited and it sprouts. This can not be prevented. The sprout lengthens and starts to penetrate the plant. Here is the next possibility of prevention, by *ventilating* the field as much as possible, so that the moisture, if not too much, may be dried up by the wind before the sprout gets into the plant, or even kept down enough to prevent germination altogether.

When this fails and sufficient moisture for infection can not be prevented, spraying and similar operations come in, by which, so far as they are successful, the spray substance kills the delicate germ-tube before it gets far enough to infect the plant. Finally, if the sprout, escaping all the plans laid for its destruction, reaches the interior tissues uninjured, the only hope remaining is in the plant itself. Resistant varieties or plants of great vitality may, by their peculiar qualities, resist the action of the fungus in their tissues and not respond to its effects.

This covers the whole field of summer-rust prevention.

FIG. 23. Black (Teleuto) Rust.

BLACK RUST, OR *Teleuto* STAGE.

This has been briefly described in its general features. Often called the *fall* rust, its appearance is by no means limited to that season, but is then most abundant and characteristic. As the writer has shown,[1] this form is that assumed by the rust under any conditions unfavorable to it, whether because the air is very dry, the plant weak and exhausted and furnishing little nutriment, or, as most common, when winter approaches and the rust must live over in some form until spring. The insufficiency of the other two forms of spores for such a function has been shown. They could not live through the winter, but would sprout on the ground as soon as moistened. In dry weather they would soon lose their vitality. They are easily affected by parasites, and in every way more adapted for spreading the rust rapidly when conditions are favorable, while with the teleutospores the contrary is true.

The appearance of the black rust is quite different from that of the other stages, both to the eye and under the microscope. The spore pustules are black and free upon the surface, rather than under a

[1]Botanical Gazette, loc. cit.

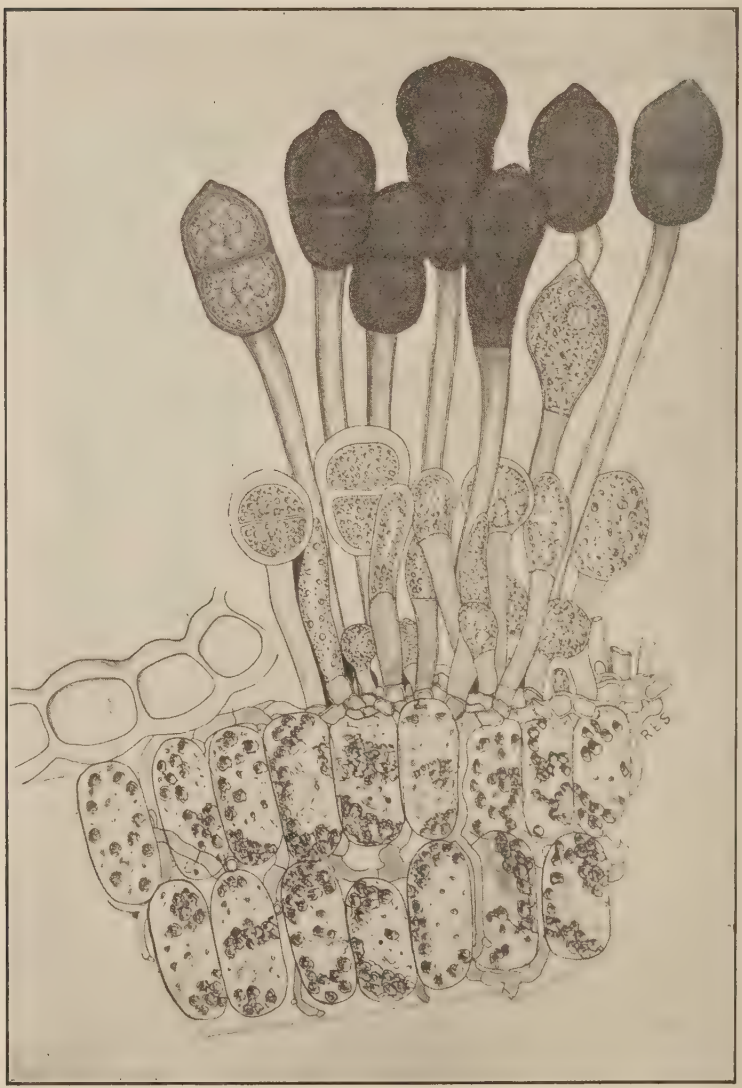

FIG. 24. Section through black rust pustule, showing Teleutospores.

blister of the epidermis (Fig. 23). In many cases, early in the season, mixed pustules of red and black spores occur, giving a brown color, but in the fall and winter, on the dead asparagus branches, the rust is black and very prominent.

Fig. 24 shows a partial section of a pustule of black rust. The spores, as seen, are dark-colored, thick-walled, two-celled, and borne singly on long stems which come up from the mycelium. Structurally they require no further description. These spores are not dusty like the summer form, but stick firmly to the plant in the original clusters where they grew. When disturbed they give off no dust (the old tops sometimes become moldy with other fungi) and show no adaptation whatever for rapid spread through the air. The peculiar office of these spores, which are produced so abundantly in the fall, is to carry the fungus over winter. After the red rust has done its work and the asparagus tops are yellow and exhausted, the masses of black spores develop on the same needles and branches and from the same mycelium as the red form which preceded them. With the fall rains, storms, and death of the tops, the needles and finer branches fall to the ground, leaving the bare stalks standing. All are covered with black rust. It is customary and everywhere recommended to cut and burn the old tops at this time, to get them out of the way and destroy as much rust as possible. But if the surface of the ground be closely examined it will be seen that there is rust enough left in the field even after raking and burning the old tops as thoroughly as can be practically done. Fig. 25 represents a bird's-eye view of the surface of the ground in a rusty asparagus field in December, after the tops had been cut and burned. The rusty twigs and needles are seen in great abundance, while the surface soil is full of older withered needles with the rust spores upon them. Fig. 26 shows such old dead needles from the soil and the pustules of black rust upon them. Examined with the microscope, the masses of spores are found still intact, just as they grew, although little is left of the asparagus needle.

Teleutospore Germination and Infection.—If the black spores in summer or fall be placed in water and under conditions in every way favorable, they show no indication of germination or sprouting. This is to be expected, since otherwise they would all sprout and perish in the fall, when no asparagus was growing to carry on the fungus. Table II shows the results of germination tests with teleutospores.

TABLE II.

Source.	Gathered.	Tested.	Germination.	Remarks.
Bouldin Island	June 8, '03	June 20, '03	None	
Bouldin Island	June 8, '03	July 2, '03	None	
Bouldin Island	June 8, '03	July 9, '03	None	
Bouldin Island	June 8, '03	July 18, '03	None	
Bouldin Island	June 8, '03	Sept. 28, '03	None	
Bouldin Island	July 15, '03	July 18, '03	None	
Milpitas	Sept. 22, '03	Sept. 28, '03	None	
Bouldin Island	Oct. 1, '03	Oct 6, '03	None	
Grand Island	Oct. 1, '03	Oct. 6. '03	None	
Vorden	Oct. 1, '03	Oct. 6, '03	None	
Milpitas	Oct. 12, '03	Oct. 28, '03	None	
Bouldin Island	Oct. 20, '03	Oct. 28, '03	None	
Milpitas	Nov. 19, '03	Dec. 12, '03	None	
Milpitas	Dec. 1, '03	Dec. 12, '03	A few spores sprout	First frosts and considerable rain latter part of November.
Milpitas	Dec. 23, '03	Dec. 25, '03	More than last	
Milpitas	Jan. 6, '04	Jan. 6, '04	None	Tested at outdoor temperature.
Milpitas	Jan. 9, '04	Jan. 9, '04	Very few germ.	Heavy frosts and freezing temperature, Jan. 7–10.
Milpitas	Jan. 9, '04	Jan. 14, '04	Many germ.	
Milpitas	Jan. 23, '04	Jan. 24, '04	Some	Kept at 90–100° F.
Milpitas	Jan. 23, '04	Jan. 24, '04	None	At about 60° F.
Milpitas	Feb. 14, '04	Feb. 14, '04	Many	
Milpitas	Feb. 18, '04	Feb. 26, '04	Abundant	
Milpitas	June 27, '04	June 27, '04	One spore germ. in many tests.	Used spores from old last year's stalks in abandoned field.

From these tests the nature of the conditions which promote germination is quite evident. Like some seeds, the teleutospores require a period of rest and particularly the influence of frost and winter storms upon them to make them sprout. It is seen that with the first frost the spores began to show signs of germinative capacity, which increased more and more as the winter progressed. Variation in the results of the tests from week to week are no doubt due largely to variations in the temperature and moisture at which the test was made. In most cases the old rusty stalks were gathered from the field on the dates given, soaked up in warm water, and then placed over night or longer in a moist chamber at living-room temperature. The tests on January 6 and January 23 at lower temperatures indicate that a fair degree of warmth is necessary to start germination, so that spores would not sprout out of doors until the first warm days of spring. The extreme weather of January 7-10 seemed to retard germination for a short time, but after a few days the spores sprouted more vigorously than ever.

In brief, we may conclude that the conditions which start the asparagus into growth in the spring are identical with those which promote germination of the teleutospores, so that the parasite is ready to attack its host whenever it starts into growth. The first rust of 1904

was observed by the writer on February 9, after some warm days which started a few asparagus stalks into growth. This was in an abandoned field where the rusty last year's stalks were not cut or the ground dis-

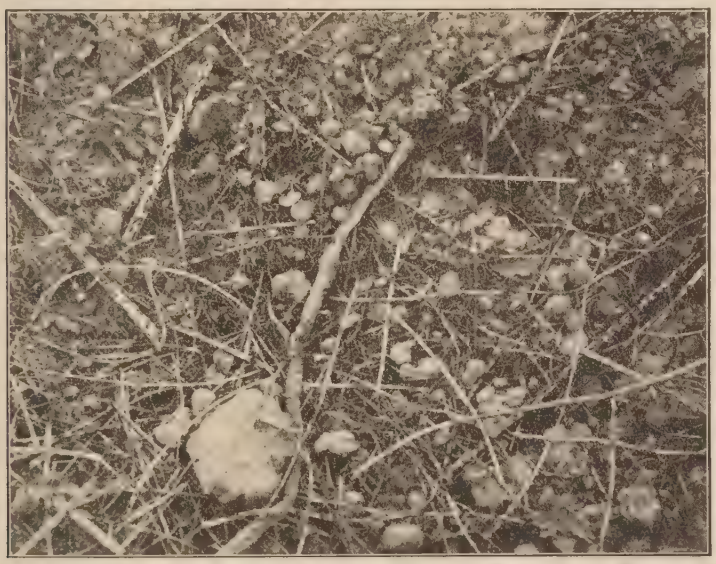

FIG. 25. Bird's-eye view of surface of the ground in rusty asparagus field in fall, showing rusty twigs and needles.

turbed, so that the new growth coming up in the midst of the old was exposed to infection to an unusual extent.

The test of June 27 with last fall's black rust shows that by that time vitality was practically extinct in the old spores, or that all had germinated previously. This accords with experience, as there is no infection in the fields as late as this, except from the new rust of the season on early asparagus tops.

FIG. 26. Old rusty needles from the soil in fall.

The germinative process in the teleutospores is peculiar, and quite different from that of the other forms. Fig. 27 represents the germination of three spores. Each cell sends out a germ-tube at the points represented, which grows up for a short distance, thick, short and club-shaped, then divides at the end into four divisions. Each of these cells puts out a side branch, and on the end of this a

small secondary spore is produced, called a *sporidium*. The original teleutospores, as already explained, remain on the ground or wherever the asparagus twigs dropped. If the old stalks were not cut the spores are still on them as long as they exist. There is no dust flying-about of the teleutospores, and they ordinarily never come into contact with the new growth of asparagus which they infect. The sporidia are very small and light, easily move in the wind, and are the spores which directly infect the new asparagus in spring.

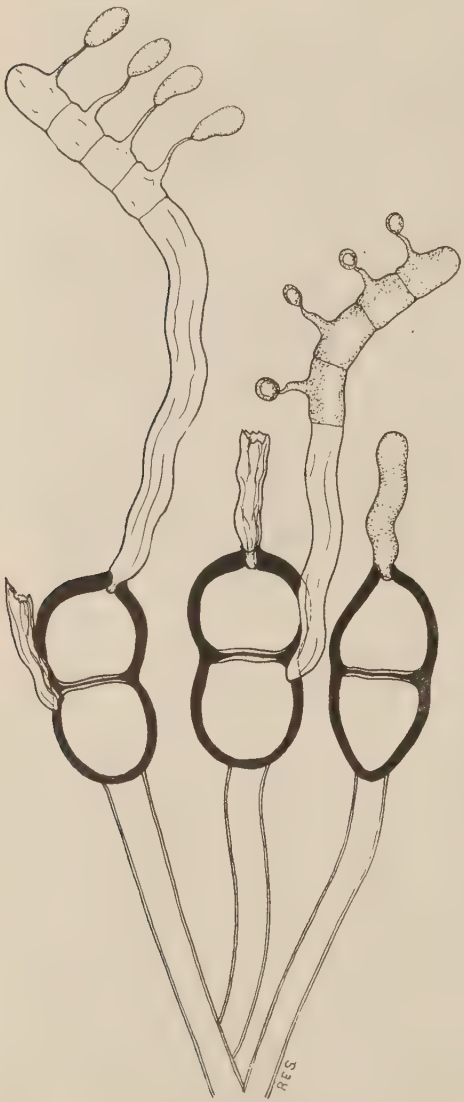

FIG. 27. Germination of Teleutospores and production of Sporidia.

It must be borne in mind that in the case of spring rust-infection, the asparagus in the main fields is being cut as fast as the stalks come up, so that these plants can not get the disease at this time. The surface of the ground, which is full of the old asparagus needles and twigs covered with black rust, is continually worked over through the cutting season from February to July, so that all the spores become exposed to moisture and no doubt sprout and then perish without causing any infection. Rust does not originate in the field, in California at least, after the tops come up in July, but comes in from the outside earlier growth. Infection from the old black rust lying over winter is limited entirely to asparagus which is not cut, to young or abandoned beds, and to volunteer, wild asparagus. Such plants grow up when the teleutospores are germinating in the soil and on old stalks, and become infected

by the sporidia. These small spores send a sprout into the plant tissue and soon develop a new mycelium. Now appears on the surface the *spring, accidial* rust, beginning a new generation. In fields of young asparagus where last year's rusty tops were removed, the first spring rust spots result from infection by teleutospores in the soil and come out near the base of the stem (Fig. 17, page 28). A crop of spring spores from these soon infest the stem higher up and others near it. In case the old stalks are left standing the new ones grow up among them and become infested at any point.

Possibility of Introducing Rust on Asparagus Roots by Teleutospores.—This is the only case in which there is any possibility of introducing rust into a new locality by importing roots, and even of this there is very little chance. The surface soil in rusty seed beds is full of teleutospores on old twigs and needles, so that when the roots are dug and the soil turned over it would not be surprising if some dirt containing spores should stick to them. These spores might then be carried wherever the roots went, germinate at the proper time, and produce rust on the new plants. In practice it is doubtful if this ever occurs. With roots shipped to any distance all dirt is washed or shaken from the roots as much as possible to avoid extra weight. When the roots are replanted they are buried deep below the surface, which would put any attached rust spores completely out of the way; the spores, if any got a chance to sprout, would probably do so before the asparagus comes up; and in every way the chances of any teleutospores, in the improbable case of their being on the roots, germinating just at the right time and place to infect the asparagus are very remote. The writer has seen repeated cases in this State where part of the roots in a rusty seed bed were replanted in new land, in one case not over a hundred feet from the bed, and a few rows left undisturbed in the old bed. The latter showed abundant spring rust on the earlier growth, while the plants that had been moved, even but a short distance, had no sign of rust until it came through the air and produced summer rust later in the season. In such a case, where the roots were dug and replanted at once, by the same men, using the same implements with the dirt fresh upon them, the chances of carrying infection are very much greater than in shipping dried and cleaned roots long distances. Practically, then, the distribution of rust in this manner is possible, but very improbable. Especially significant against the idea of rust introduction by spores on roots and seeds is the fact already stated that the disease has taken a definite course in the State from south to north, and has not appeared any sooner at places where Eastern roots were planted.

NATURE OF THE INJURY CAUSED BY RUST.

The fact that asparagus rust does not affect directly the product cut for market need lead no one to suppose that no damage results from the attacks of the disease. The cutting of asparagus shoots as fast as they start up for a period of several months is at best a most unnatural operation. That this can be done and the plant survive and flourish from year to year for a long period is indicative of great vigor of growth on the part of the crop. This vigor is located in the large root-stocks or crowns of the plant, produced and stored up for the next season by the growth of the green tops, which come up after cutting stops and nourish and build up the plant during the remainder of the season. New branches of the crown develop, eyes

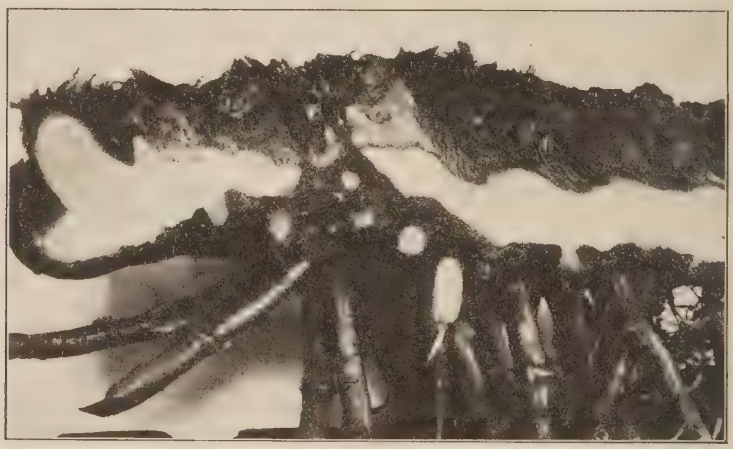

FIG. 28. Longitudinal section of healthy asparagus root-stock.

or buds are produced on these to form next year's shoots, and food material is stored up to support the growth of such shoots. Herein lies the danger from rust. The tops come up after cutting stops, ready for a long season of strengthening growth. If killed prematurely their usefulness is destroyed to that extent, the crowns are weakened, the new shoots lack size and vitality, and next year's crop shows the effect in quality or quantity, or in both. With each succeeding year of rust attack the condition becomes worse until finally the bed is killed or ceases to produce profitably.

Accompanying the weakening of the crowns a decay often sets in which further hastens their destruction. This proceeds downward from the base of the rust-killed stalks into the living tissues of the root-stock. Normally the old stalks in fall die down and are cut off

FIG. 29. Root-stock weakened and brought to decay by rust.

FIG. 30. Rust-affected and decayed roots.

from the underground crown by a clean scar (Fig. 28) like a falling leaf from the twig, but many of the rusty stalks rot at the base, the decay spreads into the crown to the live tissue, and many of next year's buds are cut off and destroyed (Figs. 29 and 30). This rotting is not caused by the rust fungus itself. There is no actual rust in the root, but by ordinary process of decay and the effect of other fungi the

a *b*

FIG. 31. *a*. Decay of asparagus shoot. *b*. Effect of wireworms.

weakened and diseased tissue succumbs to this secondary rust effect. The appearance of red spots and lines on the asparagus shoots cut in spring, with sometimes decayed spots in the same (Fig. 31*a*), an effect sometimes mistaken for rust, is to be largely attributed to the same source. The decay producing these effects appears to be started quite largely by infection from the unhealthy, partly rotten crowns, though other unfavorable conditions may produce or increase it. These red spots are simply places where decay has started, and have no direct connection with the rust.

AMOUNT OF LOSS.

The actual amount of injury from rust varies with the severity of its attacks, and quite largely with the locality, soil, variety of asparagus, and other conditions. It may be said in general, with one exception, that the injurious effects in California are not as rapid as in the Eastern asparagus districts. In such typical

FIG. 32. Asparagus stalks coming up from healthy roots after cutting season.

regions as Concord, Mass., Mattituck, Long Island, and Middletown, N. J., the loss in quantity experienced after the first severe attack of rust amounted to from 15 to 35 per cent of the crop, while in three years of rust the susceptible and most commonly grown variety became practically destroyed and the beds were abandoned. This variety, the Conover's Colossal, which formerly was almost exclusively grown on the Atlantic coast, is now practically exterminated in that region. In

California the loss has in most instances been at first more in quality and size than in number of pounds per acre. In fact, there are cases of actual increase in the latter respect as a direct result of the rust, yet this should deceive no one as to the ultimate result.

Fig. 32 shows asparagus shoots coming up from healthy roots, after the end of the cutting season. They are seen to be large and vigorous, rather few in number, and growing to a considerable height before branching. Fig. 33 shows the same growth in a field badly affected

Fig. 33. Growth from roots badly affected by rust.

by previous rust. The shoots are small, low branching, but very numerous. Fig. 34 shows the winter condition of a root such as in Fig. 32 and one such as the growth in Fig. 33 might come from. These illustrations explain themselves. The rust-weakened roots send out numerous small buds and shoots, where normally they are fewer in number and larger in size. Thus may be produced for a year or two a fair, or even increased weight, of almost worthless asparagus. The fact that these small shoots are produced so abundantly must be attributed to the long California growing season, giving the crowns vitality and opportunity for recuperation much beyond that existing under Eastern conditions. Each year, however, the condition becomes

worse, the value of the product lessens, and abandonment finally results if the rust continues to kill the tops each summer.

The exception, noted above, of unusually severe injury in California, is found in the case of asparagus growing on the pure, deep, peat soils, the relation of which to rust will be alluded to in considering the

FIG. 34. Asparagus roots, showing comparative buds on healthy and rust-affected, as in Figs. 33 and 34. Healthy above.

relations of soils in general to the disease. On asparagus growing in such a soil a loss of 50 per cent in one year has been known to occur in this State, the beds being ruined.

YEARLY LIFE HISTORY OF THE RUST FUNGUS.

The condition of the rust fungus during the various seasons, and its cycle of development through the year, now seem to be well established for California, according to the description which has preceded. This phase of the subject is of particular importance in considering methods of controlling and preventing the disease, since an exact knowledge of

the condition of the parasite at all times, and of the relations which attend its metamorphoses, should form the basis of any satisfactory plan of control, and may often suggest simple cultural methods by which valuable and inexpensive results may be obtained. From the account of the various stages and spore-forms of the fungus we may summarize the main facts in its development as follows: Starting in the spring, the earliest asparagus stalks to come up, in regions where rust occurred the year before, become infected with the rust fungus on the main stem near the ground. This comes from spores of the black, teleuto rust, which lay in the ground over winter. On the stems thus infected, the spring, æcidial rust appears. The spores of this stage soon mature and, carried by the wind, spread to the side branches and upper part of the plant and to other asparagus stalks in the vicinity. Thus the spring rust develops, in more or less abundance during the time from February to July, on wild asparagus, on young beds, and on anything not cut for market. The spores sprout at once when moistened the first time, and if no moisture occurs they lose their vitality in two or three weeks.

In May or earlier the affected asparagus begins to show the red, uredo rust, as well as the æcidial form. This produces more abundant and more dusty spores and distributes the fungus by wind very rapidly under favorable conditions. All this time the producing fields are being cut. At the end of the cutting season *all the rust is somewhere on growing asparagus.* There is none in the soil of the main beds. Cultivation through the long cutting-season has eradicated that which was present in the fall. Observation of the first appearance of rust in the fields in July or later, indicates in every instance that *it comes from the outside, from rusty asparagus somewhere else.* The plainest illustration of this is seen in cases like Fig. 35, where wild asparagus grows about the edge of the field, or where one rusty field infects an adjoining clean one; but even in cases of considerably isolated plantations the rust at first is seen to drop in here and there on the tops, brought long distances by the wind, and does not start on the lower main stems as occurs in infection from the soil.

The red rust spreads over the field, killing the tops, working from above down, and not, as in the soil-produced spring rust, from below upwards. Finally the red changes to black, the green growth to brown dead-looking stalks, and the season is ended. All the uredospores germinate when moistened, and keep their vitality when dry only a few weeks; consequently they have no apparent relation to the wintering of the fungus or its survival from year to year.

The black teleutospores remain attached to the dead needles, twigs and stems upon which they were produced. The finer stuff falls to the

ground and covers or becomes mixed with the soil. The main stalks stand until removed or destroyed by the elements. These spores do not germinate at all during the year when they were produced, but lie exposed to the rain and frost through the winter. After being acted on by frost, and being constantly more or less moist, they begin to sprout with the first warm weather of early spring, at about the time when the first asparagus shoots start to come up. If these happen to be such as are not cut, but allowed to grow up, they become infected from the spores in the ground and soon show the oval, spring rust spots on the main stems. In the fields which are cut the spores in the ground

FIG. 35. Wild asparagus at edge of field (on the left).

likewise sprout, but finding no growing asparagus they perish, and during the whole cutting season the surface of the ground is repeatedly stirred and turned over, so that all the spores sprout and lose their power of infection before cutting stops. Thus the yearly cycle is completed.

The most suggestive feature in the life history of the fungus thus established is the condition during the spring season of about four months, when the main asparagus fields are being cut and have no growth above ground, while the fungus at the same time has left its dormant winter condition and requires growing asparagus to continue its existence. The all-important question from a practical standpoint

is: Does the rust absolutely depend on growing asparagus at this time for its existence, or can it, in any other possible way, pass from the end of one season over to July of the next when the beds grow up, without living on asparagus tops in the meantime? That the former case is true in California can scarcely be doubted. In the worst affected regions where the tops have been dead and covered with black rust early in the fall, and the ground covered with rusty twigs and needles, as in Fig. 25, page 39, the progress of the disease next year can be traced precisely from wild growth or young beds into fields which grew up early, from the side and even from the plant nearest the wild growth, out across the field, from such fields to adjoining ones and those which were cut later, and so on over the whole district. In such regions asparagus grows wild everywhere, old, abandoned fields which are not cut are often present, and the conclusion is almost absolute that *on the cutting fields rust comes always from wild or earlier growing asparagus, not from the soil or plants of the field itself,* though the latter was covered with rust spores the previous fall. In some of the larger and newer districts no wild asparagus exists and the fields are located several miles from any other asparagus. In these cases the rust appears late in the season and comes on in a scattering manner, apparently brought by the wind from a considerable distance after the disease becomes abundant in other places. With so much rust in various scattered localities in all directions, it is not remarkable that spores should be brought into some part of these extensive fields, whence the disease soon spreads all over them. Furthermore, the large growers have young fields, not cut, all of which show more or less spring rust and help to spread the disease into the older fields when they grow up.

It should be said that in other portions of the country the æcidial spring rust is by no means as abundant as in California. In the colder portions where the winter is long, it occurs rarely, if at all. In the vicinity of Long Island and New Jersey it is fairly abundant, but appears in June rather than in February and March as in California. It is still a question how the fungus passes from year to year in the colder regions. The occurrence of 1897-98 in Massachusetts, for instance, when the rust was abundant during the former year, but appeared only in September in 1898, and in the black teleuto stage, suggests the question how the fungus existed from October, 1897, the end of that season, to September, 1898, when in almost every instance it first showed itself for that year. One affected field is known to have existed earlier in the season, so that possibly enough rust was present in a scattering way to start the general infection later in the season when conditions became more favorable. Still more remarkable is the case of the bed mentioned by Stone and Smith, well known to and

repeatedly examined by the writer, where each year a few plants at one end of the bed showed a very little black rust in September and October. There certainly was no rust in this bed earlier in the season, and while it may have blown in from outside this does not explain the same plants being affected each year. Their condition was otherwise in no way different from that of the rest of the bed. The case of the asparagus rust in such regions of little or no spring rust is somewhat like that of the chrysanthemum rust, which develops only the short-lived uredospores, yet exists from year to year. Structural studies give no evidence of a perennial mycelium in either case.

RELATION OF NATURAL CONDITIONS TO THE RUST.

CLIMATIC INFLUENCES.

The writer has already published in Circular No. 9 of this Station, and more particularly in a technical paper[1], the results of observations on the influence of climatic conditions on the development of the rust fungus. It is, therefore, unnecessary to repeat here the details of such observations and conclusions. It has been demonstrated beyond doubt that atmospheric dryness retards the rust, both by preventing the germination of the spores, and even by retarding the development of the fungus after infection has taken place. It has been shown that in portions of the great river and island section the air becomes extremely dry in summer by reason of the exclusion of water by levees and pumping, and because of the strong west wind which prevails all summer, and that by reason of this atmospheric dryness the rust is greatly checked and develops only late in the season where the condition is active. Proof has also been given of the fact that a certain amount of *dew* is necessary for the development of the disease, and that without this or other moisture on the asparagus tops no rust whatever will ever appear, so that conditions which favor the formation of dew favor the rust, and vice versa. These facts, which have great practical importance, are fully established and illustrated in the publications alluded to.

SOIL INFLUENCES—PHYSICAL AND CHEMICAL PROPERTIES.

Moisture.—The relations of soil moisture to the rust have also been fully treated in the above publications. It has been shown, both here and in the East, that, ordinarily, asparagus in light, dry soil is worst affected by the disease, and that irrigation of such soil helps decidedly in controlling the trouble by giving the plant more strength and resistance. This was fully demonstrated and illustrated in the publications mentioned, and is to be seen everywhere in our asparagus dis-

[1]Botanical Gazette, loc. cit.

tricts where the soil becomes very dry, except in places where extreme dryness of the air checks the rust to such an extent that the amount of soil moisture has no influence.

The following pages, quoted from Circular No. 9, summarize the relations of the rust problem to atmospheric and soil moisture:

"*Natural Conditions Affecting Asparagus Rust.*—It is gratifying to announce the discovery of several methods by which the peculiarities of the California climate may be taken advantage of in preventing this disease to a degree impossible in any other asparagus-growing State. This comes about particularly in connection with the dry, rainless summer. Experience in the East has shown to a considerable extent the effects of moisture, both soil and atmospheric, upon the development of the rust. The Massachusetts Experiment Station early pointed out the greater susceptibility to the disease of asparagus growing upon light, sandy loams (the typical Eastern asparagus soil), particularly in dry seasons, and recommended planting upon heavier soils, even if otherwise not as well adapted to asparagus, and also urged the practice of irrigation in dry seasons. A tour of the Eastern districts at present, after seven years of rust, will readily convince one of the soundness of this theory.

"Another idea brought out was that heavy dewfall favored the disease, and that the amount of rust varied with the amount of dew. On account of the general occurrence of comparatively heavy dews in the East, this observation has never been of much practical importance. In this connection it may also be said that wherever the rust has occurred it has almost always been noticed that asparagus growing directly under the shade of trees remains free from the disease when that in the open is badly affected. This had also been noticed in California.

"In this State it is well known that great differences occur as to summer dews, from regions where they are frequent and heavy, to those where there is absolutely none, a condition not even approximated in the East. In observing asparagus rust about the State the fact has been positively established, that *the amount of rust varies directly and exactly with the amount of dew, and that so long as there is little or no dew there can be no rust.* As applied to those regions where practically no dew whatever occurs in summer, this means that asparagus can be grown there with no danger of the disease. In the dry country about Fresno, for instance, several small patches of asparagus are growing, free from rust, while in a river bottom near by, where moisture is plenty, the disease is at its worst. The same freedom from rust occurs in small asparagus fields in the Coachella valley near Indio, while at Riverside and all over southwestern California rust abounds.

It is not intended by this to unreservedly recommend such places for asparagus culture. Freedom from rust is only one factor of success subordinate to many others which only experience can test. Furthermore, the present investigation was not undertaken to find new regions for asparagus, but to help those already in existence. The above remarks may, therefore, be taken for what they are worth to those interested in the districts concerned.

"Considering the regions now devoted to extensive asparagus culture there is found a considerable difference as to the amount of summer dew. In some of the localities adjacent to the lower end of San Francisco Bay conditions are almost as in the East, the asparagus tops being frequently drenched with dew until late in the forenoon, even in August. In such places the rust becomes abundant on asparagus as soon as it grows up, at any time in the season. This condition is not equally bad in all the Bay region, as the upper portions are more exposed to the trade-winds, which have a drying effect. Coming to the island district, above the straits at Port Costa, this strong west wind blows almost steadily during midsummer over the country between Mount Diablo and the Livermore hills on the southwest, and the Montezuma hills on the northeast. It is strongest and most constant in the range of Antioch, Brentwood, and Sherman and Jersey islands, well sustained at Andrus and Bouldin islands, and considerably weaker, but by no means lacking, from upper Grand Island up to Sacramento.

"Continued observation has shown that in this wind there is more help for the asparagus-growers in the sections mentioned than in any other one factor now known. Although lying so low as to require protection by extensive levees, mostly below the river level, these islands and adjacent country have a comparatively dry atmosphere in summer, owing to the prevailing wind. The amount of irrigation has, of course, an important local influence, and this and the matter of windbreaks are of foremost importance in respect to the rust.

"Most of the existing plantations of asparagus are just inside the levees, heavily irrigated, and sheltered by willows and bends and coves in the levee. These places have proven in almost every case to be the starting points of the rust.

"Fig. 36 shows just what is meant. In such corners, sheltered by willows on the west, dew is quite abundant and the rust gets a vigorous start, often three or four weeks before appearing out in the open. The advisability of avoiding such places is therefore obvious. *The cutting-down of all willows and other growth forming such shelter is most strongly urged.* Nothing so simple and at the same time so effective in checking the rust can be done. Besides this, all low spots should be avoided in planting new beds, as these also favor dew and give the rust an early start.

"Another important feature is seen in the *direction of the rows and their distance apart*. Fields with rows running north and south (across the wind) rust considerably sooner on the sheltered, east side of each row than those in which the rows run with the wind so that it can blow down the row on either side. For the same reason it is advisable to plant the rows ten feet apart in this windy country, to secure the full benefit. Repeated demonstrations prove conclusively that by planting a little back from the levee, in level, open country, keeping down all windbreaks and running the rows as described, the rust can be held back at least a month in the river district. Were it not for the old beds with their sheltered corners starting the infection

FIG. 36. Corner of asparagus field in island district, sheltered on north and west. Typical starting-place of rust.

long before it would otherwise occur, this would be even more effective, and growers are urged to grub out such places as soon as they become affected, or, better than nothing, keep the tops cut in summer.

"The matter of *irrigation* is also very important. In much of the river country water is applied abundantly and often excessively all through the summer. For the prevention of dew and the resulting rust the less irrigation after cutting ceases the better.[1] A good wetting up to July first, followed by thorough cultivation through the season, will carry through any of this land and keep the top of the ground dry. Dryness of the soil is also desirable in this region, in order to check the continual coming up of the new shoots, which goes on all through the fall.

[1]This applies only to the river district.

"Fig. 37 shows a method by which the rust may be absolutely prevented, but, of course, is not applicable to commercial asparagus growing. This consists of a simple cheesecloth tent placed over the bed when cutting stops. In regions of heavy dew two thicknesses of the cloth will be required to prevent the rust entirely. The present scarcity of healthy asparagus roots for planting suggests the use of such a method in seed-beds, where at comparatively small expense plants free from rust could be easily produced.

"The Bay regions where dew is abundant have an asparagus soil of a sedimentary nature, wet in winter and usually heavily irrigated in the cutting season, but quickly drying out in summer. Many of these beds are given little attention after the cutting season, and become

FIG. 37. Tent over asparagus; a rust preventive.

choked with weeds and extremely dry. Here the conditions existing in the East come to light. Moisture being abundant in the air, heavy dews are frequent and remain late in the forenoon, even on the driest soil. Here are repeated the conditions which occur in New Jersey, eastern Massachusetts, and Long Island; the plants suffer for water (in the soil), while the rust spores find an abundance (in the air). Consequently, the parasite thrives upon the weakness of the plant. In every case observed in this district the wettest beds remained green the longest, while good cultivation helped out in no small degree. The next figure[1] shows a striking case where the plants next the ditch were green and vigorous long after those farther back were dead with rust.

"Irrigation alone will not suffice to save these beds from rust, but will be of great assistance. It should be resorted to, however, only in the district about Milpitas and Alviso, or wherever the dews are heavy

[1]See Circular No. 9 and Bot. Gaz. loc. cit.

all summer and the winds uncertain. Without dew no amount of dryness in the soil can bring about rust."

Mechanical Structure.—The relations of the mechanical composition of the soil to rust, its coarseness, fineness, heaviness, amount of vegetable matter, etc., are largely a matter of effects of these qualities upon soil moisture. The heavier soils ordinarily retain the most moisture, and these, with other things equal, produce more vigorous growth of asparagus and a greater degree of rust-resistance than the lighter and drier soils. But naturally, in California, where we expect to irrigate any soil requiring additional moisture, the nature of the soil is considered more from the standpoint of asparagus requirements, than of rust relation. The fact that all over the country the heavier soils show less asparagus rust than the lighter ones is due, as already stated, to their greater water-retaining capacity, rather than to any more direct effect.

In the principal California asparagus districts a considerable difference in the effects of rust on different soils is seen, beyond that connected with the water relation. Of the two principal types of asparagus soil, the sediment and the peat, asparagus in the latter is considerably more damaged by the same amount of disease than on the former. This refers to formations of pure peat to a considerable depth. On such a soil, composed almost entirely of vegetable matter and water, a very luxuriant, quick-growing, tender and succulent asparagus is produced, with straight, white stalks, very desirable for canning. But in such plants there appears to be lacking the element of stamina or resistance to injury. When severely attacked by rust the roots become greatly weakened, and, on account of the water-soaked condition of the spongy soil in winter, decay takes place more readily and proceeds more rapidly than in sediment soils, and the plants have less chance for recovery. It is also true that in the moister peat soils new shoots of asparagus keep coming up continually until November (Fig. 12), and the presence of this tender young growth is another reason why on the peat lands the rust is more destructive than elsewhere when in equal abundance. This does not mean that there is more rust on the islands than at Milpitas or Sacramento, for the opposite is true, but that the same amount of rust does greater damage in the river country on the deep peat soils, for the reasons stated. The moist condition of the soil, producing continual new growth and quick decay of affected roots, is largely to blame, but there is also the difference in stamina alluded to. It has been quite marked in the history of the rust in California that asparagus in the pure peat soils of the San Joaquin side of the island district is more damaged by one year's rust than that on the sediment loams, as in the Milpitas district,

has shown in three years. It should be understood that this applies to soils composed of peat to a considerable depth, where the asparagus roots reach no other stratum. Many of the islands and reclamation districts, particularly those reached by the Sacramento River water, present a varied soil of peat, clay, and sediment in all proportions and various more or less definite formations. In some a surface layer of peat exists, underlaid at no great depth by clay. Other localities show a more or less homogeneous mixture of peat and sediment, while still others run in streaks and irregular deposits as formed by the original streams, sloughs, flood water, tule and other growths, and all the various elements which have been at work through the ages building up this remarkable region.

The whole matter of soil relation presents itself to the practical asparagus-grower, and must of necessity do so, more in the light of adaptability to the crop than of relation to the rust. Good canning asparagus, with the straight, white stalks which alone are desirable, can only be produced on soils mechanically adapted to such growth; and with a soil particularly satisfactory in this respect, even though less resistant to rust, it may be more practical to overcome the disease in other ways than to attempt to grow the crop on a soil not as well adapted to producing good asparagus, even though with more rust resistance. Yet, in the island country where large planting is going on or contemplated, much difference exists in the rust relation above pointed out, on soils otherwise equally adapted to the crop, and this matter should receive full consideration under such circumstances.

Chemical Composition.—As regards fertility, or the presence or absence of any particular element in the soil, little can be said of any definite relation to the occurrence of asparagus rust. It is true, in a general way, that plants well nourished and in vigorous condition are least badly affected, yet the disease sweeps over the fields with little apparent difference in this respect. Only in the course of several years of rust does any effect of this sort appear, yet it is true that in the end the superior condition of the well-fertilized beds shows itself and proves the value of supplying the plant with all the nourishment of which it can avail itself. Under California conditions asparagus is grown mostly without any addition of fertilizing material, except in some of the older districts where stable manure is used. With good cultivation the production is very large from the natural fertility of the soil, so that there has been no incentive to the use of fertilizers. As a rust preventive the use of any particular fertilizing substance has never shown any effect. Nitrate of soda, the only commercial fertilizer used on asparagus in California, is certainly valueless in this respect, having no influence on the occurrence of the rust, and it may also be

said that the asparagus soils are generally rich in nitrogen and little advantage in the crop has appeared from the use of this stimulant. Experiments with other substances, particularly on the peat lands, would be of value, inasmuch as the productive life of the beds might be prolonged and the size and quality of the asparagus kept up, even though little or no effect upon the rust were obtained.

The old practice of adding salt to the soil, with the idea of supplying an element necessary to the growth of asparagus, has frequently been tried as a rust cure, but it is yet to be shown that this has any effect whatever either upon the growth of the plant or the occurrence of the disease. Asparagus is capable of withstanding a large amount of salt without injury, but the benefits of such treatment except as a weed destroyer are extremely doubtful.

SOIL CULTIVATION.

Thoroughness of cultivation in asparagus-growing, including broadly all the operations of growing the crop, is of greatest importance in handling the rust problem. This does not apply to any one method, treatment, or application, but means that, in general, in any State and under any conditions, the careful, thorough cultivator has been least injured by the rust. So much is this true that the statement is freely made by the best growers in every Eastern section, where the disease has flourishd for a number of years and practically exterminated all asparagus beds in existence prior to 1896, that the rust has been to them a blessing in disguise and that their profits on asparagus, even with a greatly diminished production, are greater than ever before. The difficulties which beset the growing of the crop have put a premium on the product and the careful attention necessary to produce it. Poor or indifferent growers have been forced out of the business, the best-taken-care-of fields have survived the longest, and their owners, by taking advantage of every opportunity to resist the destructive pest, have more than made up the direct loss. Clean cultivation and good care of the crop in every respect must be the basis of any rust treatment. Too often we see the asparagus fields, after cutting has stopped, abandoned to weeds, suffering for water, untouched by the plow or cultivator, and utterly neglected at just the time when the disease makes its attack and when the plant needs every possible advantage which can be given it.

The grower who is looking for a rust remedy which will produce good asparagus without thorough cultivation and hard work, will find little satisfaction in the results of this investigation. The very fact that poor cultivation is common, and is resulting in the ruin and abandonment of many acres of asparagus in this State, and will without doubt take place and operate in the same way with much future planting, is the best guarantee of success for the better class of growers.

THE PREVENTION OR CONTROL OF ASPARAGUS RUST.

The problem of rust control has shown itself to be a difficult one in other parts of the country, and no less so in California. Chief among these difficulties have been the abundance, vigor, and rapid effect of the parasite, and the difficulty of treating the plant by the ordinary methods used for fungous diseases. Added to this in California is the limited choice of varieties on account of canning quality requirements, precluding the general use of the variety which is being most successfully grown in other States. On the other hand, it has been found possible to turn to advantage some of the peculiarities of the California climate with results impossible to obtain in the East, so that on the whole, the problem has proved in some respects a simpler one here than in other States. It is also to be considered that nowhere has the subject received such direct attention as here, the enterprise of California asparagus-growers making it possible to devote the writer's almost entire attention to this matter alone.

It should be understood that no discovery has been made of any magic cure for asparagus rust, and no treatment developed which will successfully prevent the disease without careful attention to all the details of good cultivation, such as are necessary under any conditions. It may also be assumed that the rust is here to stay, that it will never be exterminated, but will continue its ravages whenever opportunity is allowed. Asparagus rust is more abundant in the State at the present time than ever before, and the fact that methods have been found to control the disease will not prevent the large acreage which is certain to be more or less neglected, from becoming rusty each year until it is ruined and abandoned. Such a result is already evident in the case of many fields, and without doubt much future planting will meet the same fate. In fact, this is the best hope for the business in this State, for it is already evident that, with a little encouragement and no drawbacks, the planting of asparagus in the island country would soon take place so extensively as to weaken the market very materially. A serious pest which can be controlled, but not too easily, is the most effective remedy for over-production.

The results of this investigation have shown that the rust can be controlled in California. Its occurrence may be prevented almost absolutely, or checked to an extent proportionate to the efforts expended. Theoretically, absolute prevention is most desirable, but practically it is only necessary to check the disease sufficiently to prevent injury to the crop, disregarding its further occurrence. If, for instance, in two fields of asparagus, the one uncared-for becomes rusty in August so as to kill the tops, while the other by proper care and

treatment is kept green until November, the latter may also become rusty at that time and the two look equally bad in December; but next year's crop will show the value of the treatment and the needlessness of attempting to prevent the very late rust occurrence, though an observer at that time might conclude that the expense of good care and treatment had been of no avail. Results must be measured by their practical value, and judged and applied accordingly.

PREVIOUS ATTEMPTS AT ASPARAGUS RUST PREVENTION.

Owing to the slight damage caused by the rust in Europe no particular attention has been paid there to methods of prevention. The only recommendations made have been those consisting in cutting and burning the dead tops in the fall in order to destroy the rust spores adhering to them. (See references in Bulletin No. 129, New Jersey Experiment Station.) That this is of little avail in this country has been abundantly shown, and indeed a knowledge of the matter shows that much more rust falls unavoidably upon the ground on the needles and small twigs than can possibly be destroyed by cutting and burning the dead stalks. As a matter of culture the tops are removed in the fall, but this has little effect upon the rust next year.

With the serious outbreak of the rust beginning in 1896 in America, many investigators in various State experiment stations became active in seeking means for controlling this disease. The methods considered may be reviewed under the following headings: Spraying and similar methods, Cultural methods, Location, Parasites, and Asparagus varieties, each being of practical importance.

SPRAYING AND SIMILAR METHODS.

The prevention of asparagus rust by spraying the tops with fungicides has received considerable attention in the East. Halsted[1] reported in 1898 the results of spraying with Bordeaux Mixture, Soda Bordeaux, Potash Bordeaux, and Copper Hydrate. Beginning June 16, the plants were sprayed ten times, at intervals of one or two weeks through the season. The cost of the treatment on a large scale was estimated at $10 per acre or less. The result showed only a slight decrease in the amount of rust on the tops, and came far from being a satisfactory treatment.

Stone and Smith[2] report poor results from spraying with Bordeaux mixture, sulfid of potash, permanganate of potash, and saccharate of lime, the sulfid of potash showing the most effect. The principal difficulty in spraying asparagus is mentioned by these writers, namely

[1]Bulletin No. 129, N. J. Expt. Station.
[2]Bulletin No. 61, Mass. Hatch Expt. Station.

the trouble in making the solution stick to the plant. On account of the smooth, glossy surface of the needles and twigs the liquid sprays collect in drops and run off.

Sirrine[1] sought to overcome this objection by adding resin soap to the ordinary Bordeaux Mixture, making a Resin-Bordeaux Mixture.[2] This mixture, it is stated, "adhered to the plants well and was not easily removed by rains." A special spraying machine, worked by gearing from the wheels and treating more than one row at once, was also devised in this work. The results obtained were encouraging, though not perfect. The opinion is stated that spraying twice a week will protect the young shoots as they come up, but that the rust will gradually reduce the vitality of the field even with spraying.

These accounts fairly represent the results of Eastern experience in spraying asparagus with Bordeaux mixture and similar fungicides in the years when the rust was most active. Many growers attempted to treat their fields in this way, but owing to the expense of the operation, the frequent applications necessary, the difficulty of covering the tops thoroughly, and the poor or only fair results at best, such treatment was given up and most of the old beds were abandoned and dug out. It is unnecessary to give in detail any further account of Eastern experience in spraying, as this was the usual result and the practice never became general or profitable. The brief account, by Chester and Smith[3], of successful treatment in Delaware by Resin-Bordeaux spraying, in which the statement is made that two sprayings, one about the middle of July and a second early in August, will prevent injury to the crop, would seem to apply to results obtained between 1901 and 1904, when the rust showed very little activity in the Atlantic States and the fields were almost entirely of the Palmetto variety. Certainly no such easy success can be obtained ordinarily when the disease is active and unsprayed plants badly affected early in the season.

The only other treatment by the application of any substance to the tops, of which we have any record, is that mentioned in the fourteenth report of the Massachusetts Experiment Station, page 73, where Professor Stone writes as follows: "Favorable results in one instance were obtained by the application of paris green to a young bed. In this

[1]Bulletin 188, N. Y. Expt. Station.

[2]Sirrine gives the following directions for preparing this spray:

Resin	5 lbs.
Potash lye	1 lb.
Fish oil	1 pt.
Water	5 gals.

Place the oil and resin in the kettle, heating them until the resin is dissolved, then remove kettle from fire and allow the mass to cool slightly, after which the solution of lye is added slowly, the whole being stirred. Then boil, adding the required amount of water, until the solution will mix with cold water. Add 2 gallons of this solution to 48 gallons of Bordeaux Mixture.

[3]Bulletin 63, Del. Expt. Sta.

instance a large bed was treated twice for beetles during the summer. About August 18 the red stage of the rust commenced to show somewhat on the plants, and at this time one half of the bed was treated with paris green early in the morning, when the plants were covered with dew. This treatment served to arrest the outbreak of the rust to quite a remarkable extent." This observation by Dr. Stone suggests the advantage of applying copper salts to asparagus in a fine powdered, dry condition, when the tops are wet with dew, over the liquid method so difficult to operate successfully. This idea was not, however, followed out in the East, until possibly quite recently in connection with the somewhat artificial enthusiasm over "dust spray" methods. Owing to the occurrence of very little rust in the seasons of 1902 and 1903, and its late occurrence in 1904, together with the fact that most of the Eastern fields now consist of plantings made since 1896 with a fairly rust-resistant variety of asparagus, spraying was almost entirely abandoned as unsatisfactory, and to some extent unnecessary.

WORK IN CALIFORNIA.

SPRAYING EXPERIMENTS IN 1903.

At the commencement of this investigation in the spring of 1903, work was started with the idea of testing every possible method of treatment which might prove of value in California. The fact was quite apparent that if thoroughly satisfactory results were to be obtained, some method or treatment quite different from anything developed in the East must be discovered. Frequent spraying with any substance on the enormous acreage to be treated was out of the question, even if the results were certain to be successful. What suggested itself as most practical for a spray treatment was the use of something in a dry, powdered form, which could be blown into the thick tops when wet with dew much more rapidly and cheaply than spraying with a liquid. Liquid sprays were also tested, in order to make the work as thorough as possible. Two typical locations were chosen for work: One in the region near Milpitas, Santa Clara county, the other at Bouldin Island. The various treatments may now be described.

Bordeaux Mixture.—Mr. John Meads of Alviso carried out very thoroughly a test of spraying asparagus with this fungicide. The mixture was made with 5 pounds of bluestone, 5 pounds of lime, and 50 gallons of water, and applied from barrels in a wagon with a Bean hand-power pump and one line of hose (See Fig. 38). The first spraying was made on July 17, when the tops were well up, cutting having

stopped on July 2, and five sprayings in all were made at intervals of about nine days, the last treatment being about September 1. One acre was sprayed, comprising half of a small field. This spraying was done with a constant pressure of 100 to 120 pounds, giving a very fine, misty spray. The liquid stuck to the plants fairly well, but still tended to collect in drops, and when dry showed a spotted appearance with much of the plant surface uncovered. About 200 gallons of spray per acre was used in this work at each spraying, and two men with a team of horses required nearly half a day to spray the acre.

The results obtained were not encouraging. While a difference between sprayed and unsprayed asparagus could be plainly seen at the

FIG. 38. Spraying outfit at John Meads', Alviso.

end of the season, still the best portions became badly rusted as soon as the disease got abundant, and the saving obtained by spraying was very slight and far from proportionate to the expense and difficulty of the treatment. The experiment only confirmed Eastern experience with the same treatment.

Plain Bluestone Solution.—A weak solution of copper sulfate has been found effective as a fungicide in some cases, and being extremely cheap it was thought well to test this method of treatment. Mr. George Nicholson of Alviso sprayed a piece of asparagus three times, with a solution of 1 pound of bluestone to 400 gallons of water the first two sprayings, and 1 pound to 200 gallons the last time, carrying out the operation as in Mr. Meads' experiment.

No injury to the asparagus resulted from the use of the stronger solution, but in regard to the rust no effect whatever could be seen. The sprayed became as badly affected as the unsprayed.

Copper Carbonate.—A test of the ammonia-copper-carbonate spray was made in 1903 at Bouldin Island, in coöperation with Mr. Ernest Schultz, of the Hickmott Company. The spray was prepared in the usual way with 5 ounces of copper carbonate, 3 pints of strong ammonia, and 50 gallons of water, making a paste of the copper in a small quantity of water, dissolving this in the ammonia, and then diluting with the full amount of water, making a clear blue liquid. The first spraying was done on July 31, before any rust appeared, and with a finely adjusted nozzle and high pressure the tops were fairly well covered. The treatment was repeated several times during the season.

Examined on November 24, the effect of this spraying was apparent, and the results rather better than that of the Bordeaux treatment at Alviso. The sprayed rows were badly rusted, however, and in the same locality there is no reason to rank this spray ahead of the bluestone-lime combination, since the rust started later here than at Alviso. In either case the saving obtained was too small to justify the frequent application necessary.

This comprises all the liquid spraying experiments carried on in 1903.

DRY POWDER APPLICATIONS.

Quite extensive tests of various dry substances and mixtures were made during the first year of the work with the hope that some practical treatment of this nature might result. This branch of the work was carried on both at Milpitas and Bouldin Island. On the Boots ranch, near the former place, the following powders were prepared:

1 pound Paris Green and 25 pounds air-slaked lime.
1 pound Copper Acetate and 25 pounds air-slaked lime.
1 pound Copper Carbonate and 25 pounds air-slaked lime.
1 pound Copper Sulfate and 25 pounds air-slaked lime.
Powdered sulfur.

The lime mixtures were simply stirred and churned thoroughly together. In the case of the copper sulfate, the bluestone crystals were first heated in a pan over a hot fire and roasted and crushed until reduced to a fine white powder. The asparagus selected for treatment consisted of a number of rows in the midst of a large field, going down 100 feet on each row. Each mixture was applied to three rows, making fifteen rows altogether, along with two others tested in treating at different intervals of time. Thus the whole experiment took in 100 feet in length on seventeen consecutive rows, forming a block of about one quarter acre, nearly in the center of a hundred-acre field of asparagus, and with other large fields close by. The powders were put on at first with bellows, later with a Leggett powder-gun. Commencing July 6 the treatment was made, except in the instances noted

later, once each week through the season until well into September. The work was done early in the morning when more or less dew was present on the tops. One row was treated twice a week with the bluestone mixture, and another once in two weeks, thus making the seventeen rows.

Bluestone.—Three rows were treated with this mixture once a week all summer, one row twice a week, and one once in two weeks. The first applications were made with the 1-25 formula, but later 2 pounds of the copper sulfate were used with the 25 pounds of lime, with no injury to the asparagus tops. When thoroughly roasted and pulverized the crystals made a very fine powder, mixing perfectly with the lime and covering the tops very thoroughly when wet with dew. The roasting method proved much superior to the use of mechanically ground or powdered bluestone, the latter being also quite expensive.

Copper Carbonate.—Three rows were dusted with this mixture at the regular weekly treatment. The commercial carbonate is finely pulverized and mixes perfectly with air-slaked lime. The strength of 1-25 was increased to 2-25, as with the sulfate.

Copper Acetate.—This was also obtained in the powdered form and applied exactly the same as the other copper salts, once a week through the summer, at first 1-25 and later 2-25.

Paris Green.—This poisonous copper-arsenic compound was mixed with lime 1-25 and 2-25, and applied as above.

Sulfur.—The treatment with sulfur was less thorough than that with the copper salts. Three rows were treated, but owing to the supply of sulfur running short and a lack of faith in its efficacy, the treatment was discontinued a month or more before the others, making only three or four applications altogether.

RESULTS OF DRY TREATMENT IN 1903.

Rust developed very abundantly in this field, and by September 1 the tops were practically dead on all sides of the experiment block. A difference could be readily seen in favor of the treated portion, this block showing quite green in the midst of the black tops. Examining the rows in detail in October, the most conspicuous feature was the superior condition of the *sulfured* rows. In these the uppermost tips of the stalks were rusted, and the more isolated plants, but the bushy plants and all along the rows where the tops were thick and solid, the growth was still green, with needles attached, showing a luxuriant development and healthy appearance. Even where the adjoining cop-

per treated rows were black with rust, the tops leaning over and touching each other, the sulfured rows were still green and healthy in the thick growth. Figs. 9 and 10 of Circular No. 9 show, rather poorly, the comparative condition. The effect of the sulfur on the tops was noticeably quite the opposite of that produced by copper sprays. In fields benefited by spraying, the tips of the stems and branches remain greenest and hold their needles longest, while in the thick bunches of tops the rust is most destructive. In the sulfured rows the tips rusted most, while the thickest bunches remained greenest.

It is evident from this, and a general knowledge of sulfur action, that the effect was produced by the *fumes* of sulfur, rather than by direct contact of the powder. With *copper sprays and powders* the fungicidal effect is obtained by a killing of the fungus spores from contact with the dissolved copper, which explains the poor results from such treatment of asparagus. The smooth surface and rapid growth of the tops make it practically impossible to keep the needles and branches covered with the liquid, and any spore not actually touched by the solution is liable to sprout and cause infection. Spraying later will not affect this when once in the tissue, and we often see the rust pustules breaking out vigorously directly through a thick coating of Bordeaux mixture on the surface. With *sulfur,* the powder being acted upon by the hot sun volatilizes into sulfur gas; this gas permeates all through the tops, comes into contact with the germinating spores, and may even enter the breathing pores of the plant where infection is taking place. In the thick bunches of tops where the rust finds its best foothold the sulfur also is retained in greatest abundance, while a liquid does not penetrate such places as readily. When dew is abundant, favoring the rust, sulfur is most easily held by the tops. In the little sheltered places among the tops where rust first starts the sulfur gas is retained more than in the open, and in almost every way conditions which favor the fungus can be seen, theoretically at least, to tend toward favoring the sulfur treatment. Referring to Figs. 21 and 22, on page 31, it may readily be imagined how an abundance of sulfur in the tops, giving off a gas poisonous to the germinating spores, would extend its influence to such germinating spores all through the tops, when a copper spray would have to actually touch each single spore in order to prevent infection.

This was the theory formed to account for the successful results of the sulfur treatment. It may be said that not only on the original three rows was the effect apparent, but on the next rows north of these, where the prevailing wind blew the sulfur over more or less when applied, green streaks of foliage could be clearly seen late into the season. The fact was unmistakable from every point of view that the

sulfur, though applied less thoroughly than the other substances, had an effect far superior to that of any of the others.

With the *copper powders* considerable difference in effect could be seen, but none produced results justifying their further trial in practical rust control, even though applied so frequently. In the order of effectiveness they ranked as follows: Paris green, copper acetate, copper carbonate, copper sulfate. The paris green rows were noticeably greener than those treated with the other copper powders, and better than the field sprayed with Bordeaux mixture, thus confirming Professor Stone's observation in Massachusetts; but as a practical rust treatment the results were not sufficient to encourage further trial. The rows were badly rusted in spite of the numerous and frequent applications of this poisonous substance. Still it is well to know this fungicidal property of paris green, in connection with its use as an insecticide. Copper acetate showed a slight effect, copper carbonate very little, and copper sulfate almost none. The row treated twice a week with the latter substance, standing next north of the three sulfured rows which had only three applications during the whole season, stood black and dead beside the green of the more successful treatment, presenting a striking contrast, with here and there a streak of green foliage where the sulfur blew over and stuck to the tops.

At Bouldin Island in 1903 similar experiments were tried, testing the copper sulfate and copper acetate powders, and also a commercial dust spray put out by the Bowker Insecticide Company of Boston, called by them "Special Bodo," a copper-lime or dry Bordeaux mixture. The results here agreed with those at Milpitas, some saving by these copper compounds being apparent, but not sufficient to justify the operation. The "Special Bodo" showed the best results and might be used to some advantage in the East. Copper acetate showed a slight effect, and bluestone scarcely any. All the rows treated became badly rusted.

This comprises all the spray work carried on in 1903. From the results obtained the fact seemed plainer than ever that treatment with any liquid was out of the question, and that dust sprays containing copper salts as the active principle were equally unsatisfactory. The unlooked for success of the sulfur treatment gave much hope of developing a practical and effective method of applying that substance on a large scale. The fact was considered as established that sulfur would prevent the rust almost absolutely; if it could be applied at the right time and in the right way at not too great expense it might be said that a satisfactory method of rust control had been found. Previous to the season of 1904 the following letter was sent to all asparagus-

growers connected with the investigation, giving the best information which was available at that time:

DEAR SIR: As a subscriber to the fund for the investigation of the asparagus rust, this is to inform you more definitely than was stated in my recent circular as to what is most advisable for the coming season. While I shall be in the field all through the season, it is impossible to see everybody at once and you will no doubt wish to be informed in good season as to the best course to pursue.

In regard to a remedy for the rust, I will say that the method mentioned on page 16 and Figs. 9 and 10 of the Circular, consists simply in applying dry *sulfur* to the asparagus tops after they come up in the summer. I do not wish to claim too much for this treatment until it has been more thoroughly tested, but give it now simply as being much more effective on the rust than any other treatment now known. It is also cheap and easy to apply. We have yet to learn how many applications will be most profitable and the best means of putting on the sulfur. In districts which have been badly affected, I would advise the trial of three applications, the first about three weeks after cutting stops, or when the tops are beginning to blossom out and become bushy, and the others at intervals of two to four weeks, according to conditions. If the nights are dry, with little dew or fog, there is no danger of rust, but with moisture in the air the disease is sure to start. What is said in the Circular will give an idea about this. Sulfuring early in the season, when the sun is hot (before September 1) seems to be much more effective than later applications. If it can be put on early in the morning, when dew is present, it will stick better to the tops and at the same time meet the rust when it is most active. This, however, will not be practical in large fields, but even that which falls to the ground is not wasted, but gives off the sulfur gas which circulates among the tops. The use of high-grade, sublimed sulfur is recommended for this work, rather than the slightly cheaper ground sulfur, which is sold quite largely. Arrangements have been made by which the growers of any section, by combining their orders, may obtain an excellent grade of sublimed sulfur at a reasonable rate.

For applying sulfur any blowing or dusting arrangement may be used; the use of a seed-sower has been suggested for large fields.

In regard to liquid sprays, I may say that I have followed very closely all that has been done in the East in this line, as well as giving all such methods a thorough trial in this State last year. On account of the expense of using such a method and the very limited success at best, I feel convinced that this is out of the question for California. The sulfur treatment is certainly much more effective and decidedly cheaper and easier to apply than any liquid spray. Still it is, of course, only on trial and growers must use their own judgment as to how extensively they will go into it this year. I am well informed as to the condition of all the asparagus in the district and shall be glad to advise each grower as to his particular case.

I would especially call your attention to what is said in the last paragraph on page 13 of the Circular, about keeping down all volunteer growth, etc. The spring rust has already appeared in certain places, and if such growth is allowed to remain until the main fields grow up great harm will be done. Even in the young beds, which are not cut, it will be better, if they show any early rust, to mow them off about a week before the end of the cutting season, burn the tops and let everything come up together. Wild, or volunteer asparagus, should hereafter be looked upon as worse than any weed which ever grew, and treated accordingly.

WORK AT SACRAMENTO IN 1904.

For 1904 plans were made to confine that portion of the work which related to spraying mostly to the development of means for applying sulfur cheaply and effectually on a large scale. Many growers prepared to test the treatment, and much work was done during the season along

this line, at least one hundred tons of sulfur being used on asparagus by growers who had supported the investigation. Those at Sacramento were the first to begin, cutting having stopped there early, on June 14. The growers were alarmed at the decided effect upon the quality of the crop by the rust of the year before, and as the fields there are small they proceeded with great thoroughness and at considerable expense, to apply the methods recommended for rust control. Some applied simply the plain sulfur treatment, while others tested various sprays and combinations according to their own or other ideas. While naturally some mistakes were made, and unnecessary or ineffective operations carried on, as in any new work of this kind, it may be fairly said that this work of the Sacramento growers proved to be the most valuable and instructive demonstration of spraying for rust control that has ever been performed, since the work was done on a commercial scale, numerous methods and combinations were tried, some did the work more thoroughly than others, the fields were close together and under practically the same conditions, and the rust was abundant in the neighborhood. In this section the disease had first appeared during the preceding summer and became very abundant in the fall, so that before October 1 all the beds were badly affected and the tops nearly all dead.

In 1904 the spring rust came on early in the season on wild and uncut asparagus, and the fungus continued to develop in abundance as the season progressed, so that by July 1 some old abandoned beds and the wild asparagus which grows in abundance outside the levee were already yellow and badly affected. The rust, in short, wherever it had an opportunity, was active and abundant. Observing this the growers began sulfuring very soon after cutting stopped and the tops had begun to come up, fearing lest the disease should get ahead of them. Between June 20 and July 1 treatment began on most of the beds which received any attention.

The first work was done with one of the numerous sulfur-blowing arrangements in the market, but the method proved somewhat unsatisfactory. The tops were not yet fully branched and covered with foliage, sulfur would not stick well, and scarcely any remained on the plants except when applied early on very wet mornings, the machine discharged only a small amount, and altogether the work was slow and promised to be ineffective. To get over a large field thoroughly and quickly, working only a short time in the morning, was quite impossible. Some worked through the day, but this was plainly of little use, as scarcely any sulfur remained on the tops, and the quantity used was scarcely a tenth of that required in a good application. This treatment was kept up for some time in a few instances, the small quantity

of sulfur required appealing strongly to the economical instincts of the Chinese tenants, but the final results showed its uselessness.

Some of the growers then conceived the idea of spraying the tops with liquid, following with dry sulfur. This allowed of working all day, and in the small fields of that section was a feasible operation, the largest growers having less than thirty acres and most of them less than twenty. Consequently after some preliminary sulfuring, most of the beds were sprayed with Bordeaux mixture, followed with sulfur while the tops were wet. The blowing arrangements were given up and the sulfur simply sprinkled on by hand, after being run through a flour-sifter. The spraying was done with a hand pump and barrel, pulled on a sled by one horse between the rows, using one or two lines of hose. Other men followed behind with buckets of sulfur, sprinkling it on by hand as soon as the tops were sprayed. This, when well done, made a very thorough treatment and required about 200 gallons of spray and one sack (110 pounds) of sulfur per acre, costing about $3.50 for materials. The labor item was quite heavy where men had to be hired especially for this work, as five men and a horse could cover only a few acres per day. The application made was not as heavy as this in all cases, some growers using much less sulfur and putting on only one sack to several acres.

A second treatment was started on most of the fields July 18 to 20. At this time rust was very abundant on everything which had not been treated, while all the beds which had received any attention were green and healthy. Consequently the necessity of the sulfur treatment in addition to spraying with bluestone was doubted by some, and they put on simply the Bordeaux mixture. Others, however, repeated the full treatment as described above, the total expense being somewhat greater on account of the tops being larger. On two places, those of Mr. Jacob Olsen and Mr. E. Rider, extending from Sixteenth to Twenty-third streets in the pocket formed between the railroad embankment and the levee, sulfur alone was being used without any liquid spray. On Mr. Olsen's place the work was being carried on by Chinamen during the owner's absence from town, with the result that a very small quantity of sulfur was used at first, and this in the middle of the day when almost none stayed on the tops. These places were also surrounded by rusty, wild asparagus on the embankments and outside the levee. Being sheltered from the wind and very favorable to dew formation, they were much the worst places in the whole district.

Mr. Rider began with a bed of young plants not cut, which were exposed to rust the whole season as much as the near-by wild growth. He treated this bed liberally with sulfur throughout the season, and

the plants remained green and made a good growth until fall. His main beds were partly planted between rows of pear trees, with the plants in many places rather scattering and not presenting the thick solid growth which is best adapted to sulfur treatment. Mr. Rider worked very thoroughly, getting out at 3 A. M. to sulfur, and watching carefully for any appearance of rust in order to make the application especially heavy in such places. The O'Brien brothers tried at the second treatment a combined bluestone-sulfur spray, boiling sulfur and lime together and then adding the bluestone. This was used on a young bed, not cut, where considerable spring rust started, but the first spraying and sulfuring seemed to check its spread, as the tops still looked green and healthy, while untreated asparagus everywhere was very rusty.

These various treatments continued through the latter part of July, this second application being finished by August 1. At this date there was a little rust appearing in Mr. Olsen's and Mr. Rider's fields, plainly coming in from wild growth near the edges of the beds. At one place the writer found one single wild rusty stalk on the inside of the levee at the edge of the field, and a corresponding patch of rust starting in the end of the row opposite, showing the importance of the relation of such growth to the problem of rust control. Ten acres, and as easily a hundred, started to rust or were checked from rusting, by leaving or removing one stalk of wild growth! One of the fields treated with Bordeaux mixture alone also showed a few spots of rust at this time. All the others were perfectly clean. Those untreated were black and dead where grown the whole season, while a bed cut at the same time as the treated ones and situated close to them was getting quite yellow and rusty.

Increasing rust during the early part of August in the beds not sulfured at the second treatment, while those which had received the full application were still free from the disease, revived popular faith in the dry substance, and the spray pump went out of use. Some who had been using Bordeaux alone stopped when partly across the field and finished with sulfur alone, and the difference in effect was quite marked. Most of the fields were treated with sulfur alone about the middle of August, but no more spraying was done. Mr. Olsen returned and applied about two sacks of sulfur to the acre on his Sixteenth-street field which had been poorly treated and showed some rust on the edges. Mr. Rider continued sulfuring, especially where any rust showed, and his fields kept green and with no rust of any consequence. The first of September showed little change in conditions. The Sixteenth-street field had considerable rust, though still looking green from the railroad. It had a fine growth, with thick strong tops and

numerous berries. Mr. Rider's and the Twenty-third-street field were green and fine. Mrs. Harding's and all the neighboring fields were green and perfectly clean, when nearly dead at the same time a year before. October 15 the Sixteenth-street field was quite badly rusted, with most of the tops dead above though still green toward the bottom. The tops had made a fine growth and bore ripe, mature berries and seed. Mr. Rider's, the Twenty-third-street place, and all the other fields were still entirely green except in a few small spots near the back slough, where a fringe of wild growth existed, and these places were by no means bad, but with patches of rust in the upper part of some of the bushes.

The connection here with the rust from the wild plants was again perfectly evident, so many spores coming continually from such a source that no treatment could prevent some infection. By the last of November, 1904, the date of this writing, the asparagus tops at Sacramento had reached natural maturity and were being cut in preparation for winter and next season. In the Sixteenth-street field they were nearly dead, with only a little green left at the bottom. The stalks were clean and sound, however, and not rotted down into the ground. The growth appeared mature and the roots uninjured, though much of the late rust which came in could have been held off by better attention early in the season when the owner was away. Mr. Rider's and the Twenty-third-street field were still quite green though rusty on top. No indication of injury was apparent. The other places did not rust at all to any extent except as already mentioned. The tops made the finest growth for several years, matured naturally, and these beds should produce normally next year.

The growers there seem satisfied that the rust problem is solved with the sulfur treatment, though some modifications and new suggestions can be made in the recommendations for next year. To the Sacramento growers especially is due the credit of taking up the work when in the experimental stage and by their own efforts establishing many valuable facts of general application and benefit.

WORK AT MILPITAS IN 1904.

At Milpitas the work during 1904 consisted almost entirely in a study and trial of methods of applying dry sulfur on a large scale and the best time of application. The fields being larger here than at Sacramento, up to a hundred acres in some instances, wholesale methods are more necessary and those covering only a few acres per day are quite useless. The fields are less thickly planted, the returns per acre less, and the business is carried on with Chinese share-farmers whose

interests and prejudices must be more or less considered. The district is also full of abandoned beds or those poorly cultivated and very much neglected, wild asparagus lines every permanent fence, some beds are leased outright and cared for neither by owner nor tenant after cutting stops, climatic conditions are very favorable to the rust, and, all in all, the problem here is the most difficult of any place in the State.

The success of the sulfur treatment, as applied in a small way in 1903, convinced all who saw the results that this was an effective means of rust-control in this section, and that there was only required an economical method of applying the substance to make its use a practical success. Mr. Boots' ingenious mind evolved the idea of a modified

FIG. 39. Gem seed-sower, as adapted for sulfuring asparagus.

seed-sower, these instruments being already in use for applying sulfur. He devised and had made the machine shown in Fig. 39. This consists of an ordinary Gem sower, mounted on a high-bodied, arched-axled truck, designed to straddle the rows, with a horse in either furrow. The pole is attached to the bed, with an arched neckyoke of iron pipe in front. No double-tree is used, thus leaving an entirely clear space for the asparagus tops. The seed sower is tipped somewhat at an angle to throw downward, the whole idea being simply to clear the asparagus tops and not break them down. Some growers used an ordinary wagon or one as high as could be obtained, but these injure the tops to a considerable extent, especially where the rows are high. The machine illustrated has a clear height of five feet, but it is believed that four feet would be sufficient. The hopper holds a sack of sulfur,

and several more can be carried on the platform, counterbalancing the weight of the driver and operator, two men being required. The operator stands at the rear of the platform, controlling the flow of sulfur by means of the levers, and with a little practice the amount to be applied per row or acre can be distributed very uniformly. Sheets of tin, not shown in the illustration, were applied above and at the sides of the outlet, to throw the sulfur down as much as possible. In practice, this contrivance was found to throw out the sulfur in a perfect cloud of dust (see Fig. 40), which settled down upon the asparagus tops, drifted up and down the rows and through the thick growth like smoke. When wet with dew the tops could be quite thoroughly

Fig. 40. Seed-sower at work with sulfur.

covered very rapidly. Good work could not be done when any wind was blowing, and after 9 A. M. the cloud of sulfur usually rose high in the air, so that from every consideration early morning proved the best time for sulfuring. Owing to delays in constructing the machine, work was not begun at Milpitas until quite late in the summer, when rust was already abundant.

Most of the growers in that vicinity waited for a demonstration of this method of application before commencing any sulfuring, so that every field treated contained much rust before anything was done; and most of them had very rusty fields adjoining and were already badly rusted on the adjacent side.

Under such circumstances the results obtained at Sacramento were not to be expected, and in many cases little if any advantage resulted

from the application of sulfur, demonstrating the necessity of thorough work early in the season.

At the Boots ranch the first sulfuring was done on August 8th, the tops having grown since June 25. Rust was quite abundant at both ends and on the east side of the field, coming in from wild growth and an abandoned bed, the tops being already quite yellow in these places. Through the body of the field the fungus was lightly distributed but spreading rapidly, while the west side, farthest from the sources of infection, was still clean. The machine was run in every fifth row (7 feet apart), and putting on the sulfur at the rate of two sacks to three acres the intervening rows could be covered fairly well. One sack per acre made a little better covering, while an allowance of two sacks per acre produced a tremendous dust cloud and heavy covering on the tops. The amount of wind and dew influenced very decidedly the distribution of the sulfur and much of the finest material spread far out over the field.

Proceeding in the way described, on rows 1,500 feet long, an average of six acres per hour could be easily covered. No small amount of sulfur was doubtless wasted, for although most of it found lodgment somewhere in the field, that on the ground between the rows was probably too far from the tops to do much good. The farther apart the rows the greater would be such waste, so that the seed-sower method would be better adapted to the closely planted fields at Sacramento, but less so on the 9 and 10-foot rows on the islands. Three mornings' work of two men and a pair of horses on the sower, and one man and a horse to distribute the sacks of sulfur, sufficed to cover Mr. Boots' field of eighty or ninety acres. There was no dew at this time, so that the sulfur did not stick as well as might be desired. After the operation the sulfur fumes were very strong in the field during sunshine. Several of the other growers proceeded to sulfur their fields to a varied extent, but all were more or less rusted at the time and some quite badly. Most of the growers used seed-sowers, although in some cases hand-shakers were employed. Some fields were not treated until the middle of August, when hopelessly rusted already. About August 20 the Boots field was sulfured again, but an unexpected shower on August 23 washed off most of the material and the work was repeated, making three applications of nearly fifteen tons of sulfur altogether, on this field. Others using more or less sulfur in this section were Messrs. Barber, Cottle, Abel, Cropley, Bellew, Nicholson, Murphy, and Meads.

The results of all of this work, compared with that at Sacramento, showed especially the necessity of thorough, early treatment, and that fields already considerably rusted can not be helped much by sulfuring

or any other treatment, since for every rust spot that shows there are probably many thousand infections already started and ready to break out, whatever fungicide may be on the surface. There was also demonstrated here in 1904 more clearly than ever the great importance of destroying wild asparagus near the fields and the difficulty of any successful treatment in close proximity to abandoned, rusty beds. Every stage in the progress of the disease could be traced from such sources and those fields situated farthest from any other asparagus were least rusted.

In regard to the results of the sulfur treatment in this section, it may be said that all the fields rusted badly early in the fall. It was quite evident that the sulfur retarded the rust in the best treated fields, but their rusty condition before the work started, the great amount of rusty growth all about them (most of which could be prevented), and the unusual rain in August, all helped to make the treatment far from successful. Most of the fields were quite yellow by September 1, while those most neglected were black and dead. In those of Messrs. Barber, Boots, and Cottle, which were most thoroughly treated, the body of the field was still green and the rust evidently considerably retarded by the sulfur, but on the edges or ends, next to other rusty growth, the tops were getting quite yellow and rusty. By the middle of October all untreated fields and those sulfured when quite rusty were entirely dead and looked very badly. In the Boots field the instructive fact was noticeable that on the west side, where no rust was present when the first sulfuring was done, the tops were still green and showed very little of the disease, while the rest of the field was very rusty. In this and the other two places mentioned the tops made a fine growth, considerably better than that of the year before, and ripened berries and seeds. They were certainly better than any of the untreated fields under similar conditions, although one or two small beds considerably distant from other asparagus kept quite green all the season.

In the best treated fields the distribution of the sulfur became quite marked late in the season, the asparagus tops showing green spots and streaks in the rusty portions, where the sulfur was applied most abundantly, suggesting that one heavy application thoroughly and uniformly made might be better than several light sprinklings. The results both at Sacramento and Milpitas indicated most decidedly that success in rust control lay in keeping out the disease from the first of the season, rather than in destroying it after once started.

In the river district some work of an experimental nature was done in 1904, particularly at Vorden on the Van Löben Sels ranch. On this place, which is situated several miles from any other asparagus, great efforts were made to check the rust by cultural methods, consisting in the best of cultivation, keeping down all willows, weeds, and other

windbreaks along the ditches, and allowing no wild asparagus to develop. Although there was a large acreage of young fields on the place, these had not rusted in 1903 (when this section was first affected) and no spring rust developed upon them. Cutting stopped July 2 and the tops made a fine healthy growth with no sign of rust throughout the summer. A supply of sulfur was laid in, but not used until late in the season.

LIQUID SPRAYING EXPERIMENTS IN 1904.

Some liquid spraying experiments were tried at Vorden which are worthy of mention. For this a portion of a small field was chosen which had rusted badly in 1903, and several hundred feet on two rows was sprayed with each of the following mixtures:

No. 1.

Caustic Soda	10 lbs.
Sulfur	35 lbs.
Fish-oil Soap	6 lbs.
Water	100 gals.

No. 2.

Bluestone	10 lbs.
Lime	13 lbs.
Water	100 gals.

This was a plain Bordeaux mixture.

The soda in No. 1 was first brought to a boil in a kettle of water and the sulfur then slowly added and boiled, with frequent stirring, for about an hour, making a dark yellowish-brown liquid with considerable sediment. The soap (a cheap, soft, brown quality) was also boiled in, and the whole made up to 100 gallons for use, straining the boiled mixture through a fine screen into the spray tank. In making this spray, set kettles used for lime, salt and sulfur preparation were employed.

No. 3.

Bluestone	10 lbs.
Lime	13 lbs.
Soap	6 lbs.
Water	100 gals.

No. 4.

Bluestone	10 lbs.
Lime	13 lbs.
Resin	5 lbs.
Soap	8 lbs.
Water	100 gals.

No. 3 was Bordeaux with fish-oil soap added, first being dissolved in hot water and allowed to cool.

For the Resin-Bordeaux mixture (No. 4) the resin was first melted in an iron pot and the soft soap then added and the whole heated and stirred until well mixed and quite soft. This was then added to a kettle of hot water and boiled and stirred for some time until thoroughly dissolved, which was not a difficult operation. The whole was then cooled and added to the ordinary Bordeaux mixture, making a decidedly sticky liquid.

This spraying was done on August 25 and 26, using the outfit shown in Fig. 41. This consisted of two 100-gallon tanks and a hand pump on a two-horse wagon, driving between the rows. A hand-rail was put upon the rear end and the two men spraying stood by this, each with a short rod handled in one hand and spraying the row on his side. One

or two men pumped and one drove and stirred. It was not found possible to drive along and spray sufficiently without stopping the team, but this arrangement made the work more rapid and less laborious than spraying from the ground. About 200 gallons per acre were required, and four or five acres per day could be covered by one outfit with the mixtures ready-prepared for them. But one application was made during the season.

Of the various mixtures the Sulfur-Soda-Soap No. 1 combination was most satisfactory in covering the tops. This made a complete, uniform covering, spreading perfectly over the glossy surface, with no tendency to collect in drops. The spray was perfect in this respect. No. 2, the plain Bordeaux, acted as usual on asparagus, collecting in drops and refusing to spread smoothly over the surface. No. 3 was

Fig. 41. Spraying outfit at Vorden Ranch. (Operator holds short spray-rod.)

much better in this respect, and No. 4 perhaps even more satisfactory and certainly more sticky than either. None of the copper sprays made the perfect surface covering of No. 1. When dry, the latter showed a light yellow sulfur precipitate coating the well-sprayed tops completely. The others had the usual blue color and showed the difference in composition by the greater or less tendency to form separate drops.

No rust appeared in this section until after the rain which occurred in September, and none to any extent until further showers had fallen in October. When examined October 13, the main fields showed scattering rust, but none anywhere of any extent; simply spots here and there in the upper part of the tops. In the sprayed field there was considerable rust on the still green tops, and on the unsprayed portion quite a good deal. The various rows with different sprays ranked in this order: 1, 4, 3, 2, the first showing scarcely a trace of the fungus, the

second and third more but only very little, while the plain Bordeaux was not much better than the unsprayed. All the spray mixtures were still in evidence on the tops, although several unusually early rains had occurred and much new growth had taken place. In the rows sprayed with No. 1 considerable burning of the youngest growth was apparent, and it was evident that the solution could be made weaker to advantage. On November 1 there was a good deal of rust on the fields, but the sprayed rows still showed the same relative condition. The unsprayed was getting quite bad and considerable rust was coming in on all the rows. By November 7 the old fields were pretty thoroughly rusted and the tops being cut. The younger beds were still mostly quite green, but naturally mature. In the sprayed field the part not treated was quite black and all green foliage lost, though the stalks were still green. The sprayed rows were much greener, with considerable foliage. On the rows with No. 1, the liquid sulfur, not much foliage remained, but close examination showed that comparatively little rust was present. Apparently the caustic nature of the spray had caused an early maturity rather than the rust. Nos. 3 and 4 had the most foliage, but really more rust than No. 1. No. 2 was a little better than the unsprayed.

A large amount of *dry sulfur* was used on this ranch after the rust appeared, in September and October; but owing to considerable rain and a lack of hot sunshine at this season, it is not probable that much saving was effected. The tops made a fine mature growth, and the disease coming so late on the old foliage can be expected to have had but little or no effect.

The sulfur treatment was tried to some extent at other places in the river section, but owing to the late appearance of the rust and to thorough cultural methods in these places, no definite conclusions can be drawn, and no injury is probable from such an occurrence of the disease. At the Andrus and Grand Island ranches of the Golden State Asparagus Company, for instance, some treatment was intended, but, owing to excellent cultivation and favorable climatic conditions, little was necessary in this line, no rust appearing to any extent until very late, when the tops were mature, even after the early rains.

This concludes the general history of spraying experiments for asparagus rust in California, so far as they have been connected with this investigation or publicly reported. Most of the outside asparagus has received no treatment and has suffered from rust according to the conditions in the various districts.

GENERAL CONCLUSIONS ON SPRAYING AND SIMILAR METHODS OF TREATMENT.

These experiments on the application of dry and liquid sprays to asparagus have shown quite plainly the following facts:

1. That sulfur, either in dry or liquid form, acting largely by its gaseous fumes, is a satisfactory rust preventive when properly applied.

2. That it can be so applied, economically and practically, in any part of the district covered by the investigation, if the treatment is properly adapted to local conditions.

3. That all contact sprays, liquid or powder, fail to give good results on account of poorly covering the plant surface, or because too frequent applications are necessary to keep up with the new growth. Of these the Resin-Bordeaux is the best, and the plain Soap-Bordeaux nearly as good.

4. That no spraying method should be resorted to until rust control by cultural methods has been carried as far as possible, and that without reasonable attention to the latter the best of spraying will probably fail. Of the various districts, treatment is most necessary in those represented by Sacramento and Milpitas, where the rust starts early, increases all summer, and much wild and abandoned growth exists which it is impossible to suppress. In these places each grower must look out for himself, and fight as best he can the pestilence which too often his negligent neighbor is fostering.

DRY SULFUR TREATMENT.

That the action of dry sulfur alone on the tops will successfully prevent rust, has been shown by the experiment at Milpitas in 1903, the work at Sacramento in 1904, and to a less extent at Milpitas in 1904. That it will not do so unless put on in season, in sufficient amount, and in such a way as to cover the tops quite thoroughly, has been likewise shown in the same and other instances. That it is most effective early in the season was shown at Milpitas in 1903 and at Sacramento in 1904, when none was applied after the first of September, and by the failure of later applications at Milpitas and Vorden in 1904 to show much effect. The conclusion has therefore been reached that one heavy, thorough application in July would be most effective in the districts where the rust spreads rapidly at that time. Sulfuring after the first of September has shown very little effect anywhere, so that this treatment can not be strongly urged at that time, and in the districts where rust occurs only after the date mentioned, other lines of treatment must be looked to for the best results. In places where the rust becomes abundant in July and August the dry sulfur has shown itself to be effective when properly applied.

Time for Treatment.—The time of beginning treatment is one of the most important considerations. This varies, naturally, with the time when cutting stops. At Sacramento in 1904 cutting stopped on June 14 and most growers began sulfuring and spraying within a week. This was evidently *too soon*, doing no harm, of course, but making unnecessary labor and expense. At Milpitas the cannery shut down on June 25 and cutting stopped soon after. No sulfuring was done until the first and second weeks in August, which was altogether *too late*. The *best time* for these sections appears to be about three weeks after cutting stops, before any rust appears, but after the tops get branched and "feathered out" a good deal. This is about the time of blossoming. For reasons of economy the work should not be done too early, and if the tops are very young and unbranched, probably very little good would be done; but where rust is abundant in the neighborhood its appearance in the field must not be waited for, but treatment applied within the time mentioned. If cultural methods prove successful in holding off the disease the treatment may be further postponed; but too early is much better than too late. With one good treatment in July, and strict attention to cultural methods (keeping down wild growth, etc.), one more treatment should be sufficient. This may be best applied, judging from experience, about a month after the first, or not later than the middle of August—not over a month apart at most. These two treatments should be sufficient if properly made and supplemented by proper care in other particulars, though judgment must be used according to circumstances, and in small beds more attention can be given than in large fields. The time must also be chosen according to the amount of dew present, if dry sulfur alone is used. It is better to wait a few days for wet mornings than to attempt to sulfur dry tops.

Amount of Sulfur.—One sack of finely pulverized sulfur per acre applied evenly, and all on the tops, makes quite a liberal application, but if thrown on in lumps, wasted on the ground, or put on when the tops are dry, little sulfur will be seen on the asparagus after the application has been made. Experience shows that one heavy application, after the tops are fairly well grown, is more effective than two light ones a short time apart, and it is believed that nearly two sacks per acre, well applied, the first time, and one sack the second, will give the best results which can be obtained from that amount of sulfur.

Kind of Sulfur.—Commercial sulfur is furnished in different grades and at correspondingly different prices. It is commonly found on the market in the forms known as flour of sulfur and flowers of sulfur, the former being ground sulfur and the latter that which has

been sublimed.* Sublimed sulfur is the most expensive, finest, lightest, and purest form. Ground sulfur varies in fineness and purity according to the care taken in its manufacture, but ordinarily contains at least 98 per cent of sulfur, and may be made very fine by thorough grinding, and by running it through bolting cloth. The various grades of sulfur range in price at San Francisco from about $30 to $45 per ton. Several commercial brands are on the market. For asparagus treatment the *fineness* of the article is the most important feature. Percentage of purity is of no practical importance, as any respectable brand contains at least 97 or 98 per cent of pure sulfur. A coarse, pure sulfur has much less value than a very fine article of less purity. A small amount of acidity is also no drawback, but possibly of value as a fungicide. Asparagus-growers intending to use sulfur in large quantities should get an exact statement or guarantee of the grade to be furnished, before purchasing, and should know definitely whether it has been ground, bolted, or sublimed. A genuine sublimed or flowers of sulfur is the most effective form for use on asparagus, being finer and lighter than any other. Next to this is to be preferred that made as fine as possible by grinding and bolting. The bulk or size of the sack gives a fair idea of the fineness of the sulfur, a sack of sublimed sulfur being nearly twice as large as the same weight of coarsely ground material. The sublimed has an actual value of several dollars per ton more than the ground for use on asparagus, since it is lighter, sticks better to the tops, vaporizes more readily in the sun, has greater bulk per ton, and, in general, goes further and is more effective. Dealers would do well to make as low a price as possible on sublimed sulfur and encourage its use. Growers who consider the price prohibitive on such a quality should obtain a finely ground and bolted sulfur. We shall be glad at any time to examine samples of sulfur or to advise as to its value and use, either for growers or dealers.

Methods of Applying Dry Sulfur.—Sulfur, to be effective in rust control, must be applied in the form of a fine, smoke-like dust, reaching and sticking to every part of the plant surface. It does little good when thrown on if it contains many large or small lumps, as these go through to the ground and present no surface to the sun. It is also ineffectual to sprinkle on a streak here and there, leaving much of the growth with no sulfur upon it. If the tops are too dry, little sulfur will stick firmly, however put on, and again the results will be poor. All these sources of failure and the ideal result desired should be kept in mind, whatever method is followed. The simplest way of apply-

*In the trade *flowers of sulfur* is distinguished as the finest grade produced in the process of sublimation.

ing sulfur is to sprinkle it on directly by hand. If the material is first carefully sifted and the tops are quite wet, this may be done fairly well, but in practice a great deal is thrown on by the handful and not sprinkled carefully through the tops. It can not be called a very satisfactory method for general use, and on a large scale is too slow if carefully done. For use on a small scale the method of application by the ordinary pepperbox-style hand-shaker is about as good as any. This is slow, but gets the sulfur on in the dusty condition desired and enables the operator to cover the tops very thoroughly. Many special appliances or "dust sprayers" are also on the market for such work, of all kinds, sizes, and degrees of value or worthlessness, some working on the bellows and others on the fan-wheel principle. The following quite complete list of makers of such machines is presented here for reference, with no comment on the merits of the individual machines:

Kiser Whirlwind Duster Manufacturing Co., Stanberry, Mo.
Graves Dust Sprayer Co., Bentonville, Ark.
Haldeman Manufacturing Co., Springfield, Mo.
Dust Sprayer Manufacturing Co., Kansas City, Mo.
Willis Dust Sprayer Co., McFall, Mo.
Leggett & Bro., 301 Pearl street, N. Y.
S. A. Haseltine, Springfield, Mo.
California Bellows Manufacturing Co., 77 Federal St., San Francisco.

Of these the bellows made by the California Bellows Co., and the Leggett powder-gun, were purchased and used in the work of 1903. In 1904 samples of the Graves and Haseltine machines were furnished by their makers for trial and found well adapted for use to the limit of their capacity. In large fields any of the smaller hand machines are too slow. For heavier work several of these firms make larger machines running by a crank handle and fan-wheel blower. A still larger form is that made by the Dust Sprayer Manufacturing Co., shown in Fig. 42, running by gasoline engine power in a walnut grove.

The seed-sower device is the only other arrangement known to the writer by which sulfur can be applied on a large scale. Of the larger devices it sends out the sulfur in the best shape. Comparing Fig. 40 on page 74, with Fig. 42, it may be seen how the sower sends out a uniform cloud of dust, settling on the tops and drifting all through them, while the blower shoots out a solid stream, not spreading until it has gone some distance, passing through and beyond the row aimed at, and tending to go off in the air rather than stay where it is wanted. The seed-sower also treats several rows at once, but is open to the objection that the row on which the machine is working gets more sulfur than the others, some of the intervening rows are apt to be poorly done, and

much sulfur goes on the ground. It works better the nearer the rows are together, and is scarcely practical where they are eight or ten feet apart. Careless operators are also apt to try to treat too many rows at once and leave some which get very little sulfur. Every row and all the tops in every row must be covered thoroughly for good results. In thickly planted fields the seed-sower will do this better and more rapidly than anything else. Where the rows are far apart it will not. The larger hand-power fan-wheel machines seem best adapted for the thorough treatment of one row at a time. Two may be put on a wagon driving between the rows, and thus double work performed. Such

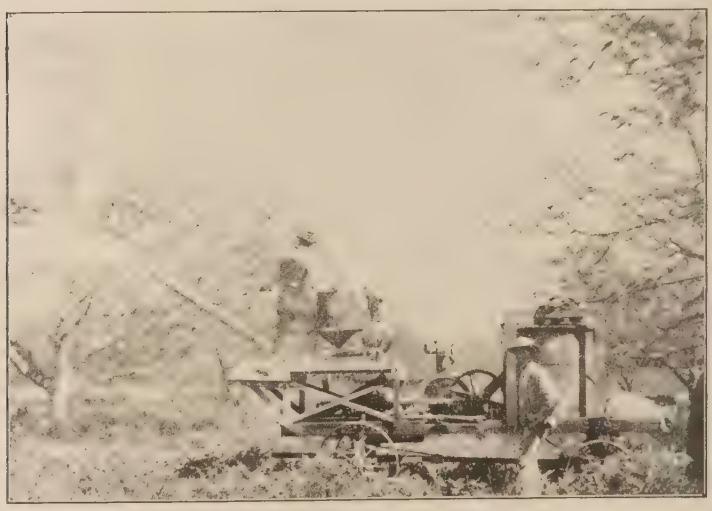

FIG. 42. Dust-sprayer in walnut grove, Rivera, Cal.

machines are the Leggett "Jumbo," the Kiser "Whirlwind," Haldeman "Tornado," and Dust Sprayer Co.'s "Cyclone."

Cost of Dry Sulfur Treatment.—Estimating sulfur at 2 cents per pound, the two applications described would cost about $5 or $6 per acre for materials during the season. With the seed-sower the labor item is very small, only a few cents per acre. Hand work is more expensive.

LIQUID SPRAYING.

The value of liquid spraying has been found to be in two directions: its direct action in suppressing the rust, and its aid to the sulfur treatment in sticking on the sulfur independent of dew. In the former respect the liquid sulfur has shown the best results, while for the latter purpose it is also most desirable on account of wetting the

surface most thoroughly. The Soap Bordeaux is more easily prepared, and effective enough to merit some consideration. The *sulfur spray* combines the action of a liquid fungicide with the gaseous effect of dry sulfur, since the sulfur goes on in a liquid state as dissolved sulfur or sulfids, killing any germinating spores with which it comes into contact, then as it dries the sulfur or sulfids crystallize out and form a solid coating with the soap on the surface, giving off sulfur gas when acted upon by the sun. Spraying with this substance seems to be without doubt the most effective single treatment for the rust. Its practical application, however, for large fields, is not economical unless it can be put on rapidly on a large scale. The composition or proportions of this spray may be improved upon by future experience, but the principle of its action, both contact and gaseous, has plainly shown its superiority to that of simple contact sprays like the copper mixtures, while its adhesive and spreading properties surpass those of any other mixture of this sort known to the writer. Bluestone should not be added to this mixture, or any substance which would materially change its general composition of sulfur dissolved in a caustic hydrate. Caustic potash might be as good as the soda, but has not been tried in this work. There are a number of sulfur sprays in use for various purposes, many of which will be tried on asparagus as soon as possible. It is to be presumed that another season's experience will add much information in this connection as to the most effective and economical sulfur spray which can be used. The general idea in any case must be to coat the tops with sulfur or alkaline sulfids in considerable concentration.

Time for Spraying.—What has been said in regard to the time for dry sulfur treatment applies equally well for liquid spraying, especially as the latter is intended mostly for use in conjunction with the former. The idea should be in any case to make the principal treatment just before the rust usually appears. If the liquid sulfur spray is the only application made, and it appears to be the most effective of any single treatment, the tops should be well sprayed in places with conditions like Milpitas and Sacramento at the time recommended for the first dry sulfur treatment or a few days later, when the tops have considerable growth but before any rust shows in the field. At least one more spraying should then be made, with or without dry sulfur, and for very thorough work in places much subject to rust, particularly in small fields, several sprayings will be found useful.

In the river section where no rust appears before September or October in open fields, and the dry sulfur is less effective on account of the lateness of the season and the width apart of the rows, one spraying with liquid sulfur about the first week in September will be

found very effective in keeping the tops green late into the fall, if this is considered necessary, though present conditions indicate that by judgment in planting and attention to cultural precautions the rust can be held off late enough in the fall, in most of this region, to prevent any damage to the crop and make spray treatment unnecessary. The time for any treatment must be guided entirely by local conditions and previous experience, the general idea being to start just ahead of the probable rust appearance and keep ahead of it until late in the season.

Methods of Applying Liquid Sprays.—The chief objections to this style of treatment have been, as previously stated, the difficulty of making the liquid cover the plant surface thoroughly, the frequent applications necessary on account of the growth of the asparagus tops, the slowness of the work and large labor expense, and the difficulty involved in transporting such large quantities of water about the field. The first objection is overcome by the use of the liquid sulfur; the second partially so by the gaseous effect of the same spray after drying, and almost entirely so in the island country by the late appearance of the disease. When dry sulfur also is used, the necessity of frequent applications is entirely done away with. The last two difficulties mentioned apply mostly to large fields, and can only be overcome by the development of spray machinery which would permit rapid work on a large scale. In small or medium sized fields, up to thirty acres, ordinary hand-pump appliances may be used. For beds of a few acres the Sacramento method of a one-horse sled carrying a barrel and pump between the rows, with two lines of hose, is quite satisfactory. A two-horse wagon with two tanks or barrels and the largest size hand-pump is the next largest outfit. The method shown in Fig. 41 and described on page 78 is the most rapid for this style of work and has proved a great improvement over that of Fig. 38, on page 63. The sprayers ride on the wagon and readily reach all over the row. But even at best these methods allow of spraying only a few acres per day, and are too slow and costly for fields of one or several hundred acres. To meet this difficulty several machines have been devised for more rapid asparagus spraying, treating more than one row at once, and pumping by power obtained from the wheels. The first machine of this kind was that described by Sirrine, and called by him the "Downs Power Asparagus Sprayer." This consisted of a 250-gallon half-round tank, mounted on a four-wheeled truck high enough to straddle a row, a pump worked by a chain on one wheel, and a rather complicated combination of piping, carrying twenty nozzles, so located and adjusted as to spray both sides of the row straddled, and one side of each of the adjoining rows, or the equivalent of two rows

altogether, as the machine was driven along through the field. Telescope and shear joints in the piping allowed of adjustment to rows of different widths and plants of different height. One acre per hour could be sprayed by two men and two horses, with considerable less material than is used in hand spraying. The cost of building the machine was estimated at about $200.

Figure 43 shows another wheel chain-power sprayer for asparagus—that made by the Aspinwall Manufacturing Co. of Jackson, Michigan. This is a two-wheeled machine carrying two barrels of liquid, with twelve nozzles for the two rows, connected with rubber hose.

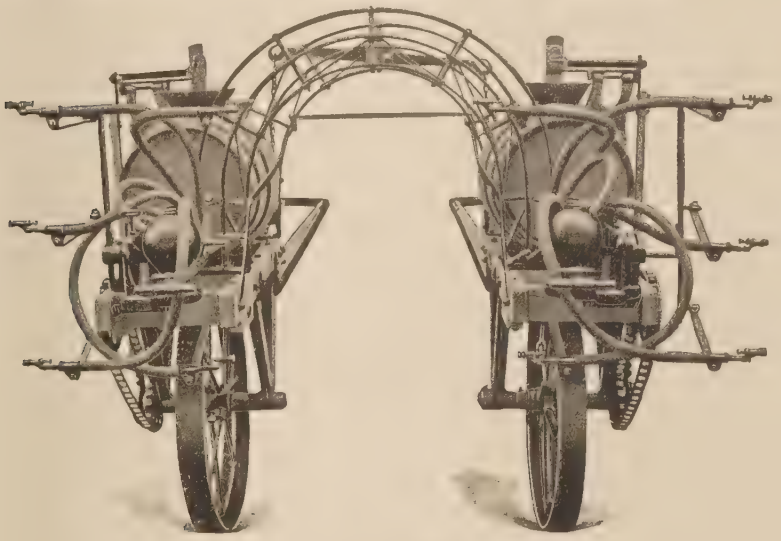

FIG. 43. Aspinwall asparagus sprayer.

Various other wheel power machines are made for spraying, some of which might be adapted to asparagus.

The chief objection to all such arrangements is that spraying goes on only when the horses are moving steadily, so that at the ends of the rows and anywhere that a stop is made considerable asparagus is left unsprayed, while the pressure often runs down if the team slows a little. The sprocket chain on the wheel for working the pump is also some extra strain on the team if a high pressure is maintained. With these objections the Aspinwall machine, the only power sprayer for asparagus on the market known to the writer, appears to be capable of effective use in competent hands and with a good spray mixture. Like the seed-sower for dry sulfur, it permits a rapid but incomplete and noneffective treatment of large areas when carelessly used by those not realizing or considering the primary object of the work and the

necessity of treating every portion of the growth as thoroughly as in hand work.

The common use of gasoline engines for spray power in California suggests such an outfit as best adapted for asparagus spraying on a large scale, and, in fact, such power has been used in spraying asparagus, both East and West. While no machine of this sort has actually been tried in the asparagus rust investigation, considerable thought has been given to the subject, and general ideas worked out, particularly in connection with Mr. Fred Bromage of the Vorden Ranch, for such a device. An outfit of this kind would probably find use only in the larger fields of the river section. Here the tops make a very thick, large growth, and the rust, appearing only in September or later, starts on the upper part of the tops and works down. The sides and under part of the growth do not rust until the top is gone, being shaded and kept dry. This feature has been illustrated in Circular No. 9 and elsewhere. For the one late spraying which at most is necessary in the Sacramento River district, a good covering of the upper part of the rows is therefore sufficient. For this purpose there is no apparent difficulty in attaching a cross pipe at the rear of the spray truck long enough to cover two rows (the truck running between them), and put in this pipe a number of nipples to cover rows at different distances apart, though as a fact almost all on the same ranch are nearly the same and none vary a great deal. On the nipple over each of the rows can be attached a yoke-shaped pipe with three or more nozzles covering the row, arranged as may prove most effective. The cross pipe may be made adjustable in height by means of a supporting frame and two or more connections from the pump. This is a mere suggestion, but it is expected that such a device will be actually constructed and tested next year. For rapid spraying of large fields there is practically no doubt that some such contrivance can be developed for asparagus, along the lines of several different sprayers now in the market for treating several rows at a time. For effective liquid spraying of much extent the spray outfit should be kept supplied with the spray mixture by a feed wagon, with help enough to prepare the spray and take it to the field as fast as used.

Cost of Liquid Spray.—The cost of materials for the various mixtures considered may be reckoned per acre as follows, allowing 200 gallons of spray:

Liquid Sulfur.

12 lbs. Caustic Soda at 8 cents	$0.96
50 lbs. Sulfur at 2 cents	1.00
10 lbs. Soap at 6 cents	.60
	$2.56

Resin Bordeaux.

20 lbs. Bluestone, at 5½ cents	$1.10
25 lbs. Lime, at 1 cent	.25
10 lbs. Resin, at 4 cents	.40
12 lbs. Soap, at 6 cents	.72
	$2.47

Soap Bordeaux.

20 lbs. Bluestone, at 5½ cents	$1.10
25 lbs. Lime, at 1 cent	.25
10 lbs. Soap, at 6 cents	.60
	$1.95

The best proportions for these sprays, particularly the first, have not been fully established, but in any case it will be seen that the cost for materials is quite inconsiderable. In power spraying the 200 gallons would cover somewhat more than an acre, while with hand work a little more than that quantity per acre might be required. The labor item in all spray work is the chief expense. Counting labor and materials, asparagus can not be sprayed with liquid by hand for much less than $5 per acre at each application. With a power outfit a considerable saving over this is to be looked for, so that one application per season would not be impracticable on account of the expense.

CULTURAL METHODS AND LOCATION IN RELATION TO RUST CONTROL.

That in the ordinary culture of asparagus much may be done toward rust control in California has been frequently alluded to. The facts upon which this rests may be gathered from the preceding chapters pertaining to the nature of the rust fungus, its development and life history. The quotation from Circular No. 9 on page 52 covers a portion of this subject as related to the planting and surroundings of the fields. The importance of what is said there grows more and more apparent in the island country as the rust increases. Planting the rows with the wind, on level, wind-exposed ground not sheltered by levee or trees, and keeping down all growth of weeds and other shelter about the fields, needs no further exposition to those familiar with the conditions. Asparagus planting in this section, in places sheltered on the west and north, incurs needless danger and expense except where other considerations are more important. The beneficial effects in rust control simply of good cultivation, keeping down weeds, stirring the ground, sufficient irrigation, etc., are also brought out in Circular No. 9 and are known to every grower of experience with rust. The condition of neglected beds is amply sufficient to show this.

Coming more particularly to methods concerning the development of the rust fungus itself, nothing can be more apparent than the great opportunity of checking its development during the cutting season, when the main fields have no growth above ground. It has been

shown that, from all experience in this State, the rust fungus must grow on living asparagus tops during the spring and early summer, and spreads thence to the main fields after they grow up, and that the further such growth is kept from the fields the later the rust will appear, the longer time the tops will have to develop naturally, and the less spraying will be necessary. With this fact established, and every observant grower knows it to be so, the simple matter of keeping down wild growth near the beds need require no further mention. It is far, and above all, the most important rust-preventive method in California, in proportion to the effort required. Destroy or keep down, by all means, every stalk of wild asparagus that can be gotten at. Dig it out, cut it down, pour crude vitriol on the roots, or anything to prevent its growth before the fields grow up. One stalk may easily start rust in a whole field, so that the watch for such growth can not be too close, especially about the edges of the fields. In young beds not old enough for cutting, growth must be allowed the whole season, and this is often a source of infection. Something can be done here, however, by cultural methods. Infection comes, as has been shown, from spores on the surface of the ground on last year's needles and twigs, sprouting in early spring and infecting the new asparagus stems. Burning last year's tops destroys some of these spores, but by no means all, those on the finer growth falling to the ground (Figs. 25 and 26 on page 39).

Cultivation in winter or fall and early spring will bury much of this material and lessen infection, so that in young beds the soil should be stirred and cultivated as much as possible after the tops are cut and when they come up again in spring. The cutting of young beds, even for a very short season as soon as they are old enough, is also conducive to preventing spring rust infection, but the leaving of such beds uncultivated on account of their non-productive condition is the surest way to favor the rust. The matter of old abandoned beds or those not taken care of by their owners is perhaps the hardest feature to contend with in districts like Milpitas and Sacramento. Many fields in these sections are practically continuous, being separated only by fences, and too often the disease comes into a well-taken-care-of field in overwhelming abundance on the edge next a neighboring breeding-place of rust, and the owner is powerless to prevent the occurrence. Whether county legislation could or does cover such cases seems the only possible remedy to consider after moral suasion fails, but compulsory treatment by spray methods would probably be carelessly done and without effect, so that the only action of any probable value would be to require the total destruction of all rusty asparagus tops existing on a certain date, say June 1, on complaint of neighboring

growers, and this again would probably be attended with much difficulty.

Fields which are thus exposed to infection from sources which the owners can not be persuaded to destroy or prevent, can only be treated by taking special pains to prevent any infection from the other sides and concentrating the efforts of spraying, etc., on the most exposed part. By early and very thorough treatment rust has been shown to be preventable in very bad places. This disposes of all the possible sources of spring rust. The inference is not intended that the occurrence of the disease can be prevented altogether in this way, but simply that it may be kept at a distance until later in the season and much of the injurious effects and expense of treatment prevented.

The matter of burning the tops in the fall needs little consideration, as this is general practice. Cutting and burning the rusty tops in summer, early enough to force a new growth, was at first tried in the East, but as the second growth rusts as badly as the first more harm than good is sure to result. At the end of the season it is better to cut the rusty stalks while the stems are still green at the bottom, as when perfectly dead from rust they decay down into the ground and eat out the crowns more rapidly. (See Figs. 29 and 30, on page 43.) Other details of ordinary matters of cultivation most favorable to producing good growth will suggest themselves to the practical asparagus-grower, the aim being to bring out here more especially the adaptation of cultural practices to the life history of the fungus and hinder its development by such practical means.

LOCATION.

Parties considering the growing of asparagus on a large scale may with much profit consider the relation of various localities and climatic and other natural conditions to the rust problem, as well as in regard to the general requirements of asparagus production, though of course freedom from rust is only one factor in profitable asparagus growing.

RUST PARASITES.

That the rust-producing organism, itself a parasitic fungus, should in turn be attacked in a similar manner seems remarkable, but is nevertheless quite true. The earlier Eastern publications describe several parasitic fungi which live upon the asparagus rust. Of these the most abundant, *Darluca filum* Cast., described and figured by Halsted, and by Stone and Smith, and mentioned by most writers on asparagus rust, is a small fungus developing upon the rust pustules, checking their development somewhat, but living more upon the mycelium than upon the spores of the rust. This fungus has been abundant

everywhere that rust has occurred since 1896 and is often to be found in this State, but its effects have nowhere been apparent in reducing or checking the spread of the disease. The other parasite mentioned by Halsted, *Tubercularia persicina* Ditt., is not as common and of no apparent practical importance. Various mold fungi may often be found on rusty asparagus in damp weather, especially in California,

FIG. 44. Parasite on rust (*Cladosporium* sp.).

but these again have little effect on the spores and can not be considered of importance in practical rust control.

There occurs very abundantly in California a rust parasite which has not been previously recorded, or seen by the writer in the Eastern States. This becomes very abundant in sections like Milpitas where the rust starts early, and from all appearances has quite a decided effect in checking the spread of the disease later in the season. In this district, and more or less so in others, when a plant or field

becomes covered with red rust pustules, a darker brown, mold-like growth develops on the rust spots themselves, never on the plant

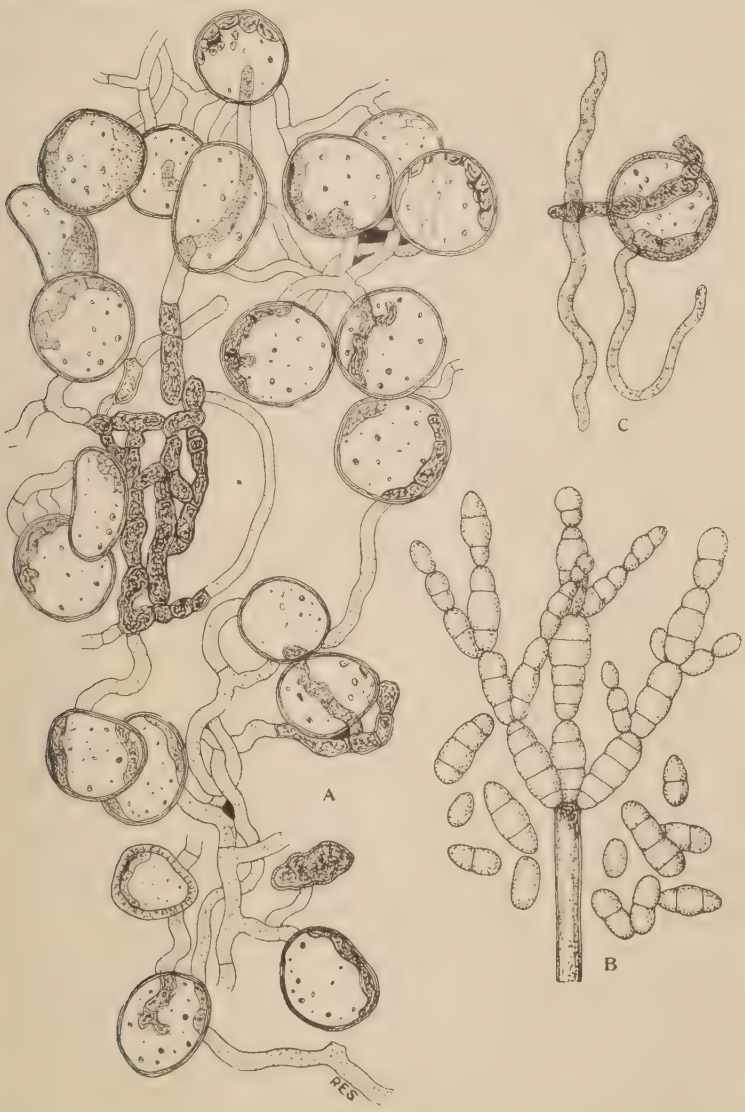

FIG. 45. *a*. Rust spores with parasite. *b*. Spore production of parasitic Cladosporium. *c*. Dead rust spores with parasitic fungus sprouting from them.

so long as it remains green, and the rust becomes completely covered with this growth. This is shown in Fig. 44 on the stalks at the left, where the rust blisters are seen to be covered with the other fungus.

The whole field, when badly rusted, becomes full of this mold and its spores make a dust cloud more profuse than that coming from the rust itself. Fig. 45*a* shows the condition of rust uredospores attacked by this parasite, the latter fungus growing into and through almost every spore on badly rusted plants and destroying their vitality. A peculiar feature is that shown in Fig. 45*c*, where dead spores of the rust which contain the parasite spread in the wind in the ordinary manner, but send out sprouts of the parasite instead of reproducing the rust. This is a form of *Cladosporium*, and shows no structural difference from the ordinary *Clad. herbarium* Link., a very indefinite species. (Thümen describes *Clad. aecidiicolum* as a parasite on various æcidia. Zopf, "Die Pilze," p. 272.) Fig. 45*b* shows the spore formation. What seems to be the same fungus is seen abundantly on dead mustard stalks, but much less on any other plant. It is certainly a very abundant mold. That this parasite is instrumental in checking the spread of the rust at Milpitas and wherever it starts early appears from the fact that the disease spreads but little in such places after September, but the fields, by new growth which does not rust, are often actually greener in October than in September. The abundant wild growth, which is killed down by rust in midsummer, also comes up again more or less and shows little rust thereafter. Certainly the disease stops spreading in September or October where it has been very abundant earlier, and spares what little growth remains or comes up new, while the late-appearing rust in the islands spreads rapidly in November. There is every indication that in sections like Milpitas, if the rust can be controlled well into September its occurrence thereafter will be greatly checked by this parasite.

VARIETIES OF ASPARAGUS.

There is no question that some varieties of asparagus are more resistant to rust than others. This difference appears much more in new beds, planted after the rust outbreak started, than in those which existed at the time. So much is this true that in the East the rust problem seems well-nigh solved by the growing of Palmetto asparagus, yet in the first years of rust the difference in favor of this variety was slight and often not at all apparent. In 1900 Sirrine[1] wrote that "The fields on Long Island have been watched every year since 1896, with the result that only slight, if any, differences in favor of the Palmetto were to be noticed, except that in some cases it did not succumb as early"; yet at present in the same fields the Palmetto alone remains and is being extensively planted. Mr. Wm. Conover planted a field on his place in New Jersey with three rows of Palmetto, then

[1]Bulletin 188, N. Y. (Geneva) Agr. Expt. Station, 1900.

three rows of Conover's Colossal, alternately, and after a few years the Palmetto was still green when the other variety was practically exterminated so that those rows had to be replanted with Palmetto. There is no doubt whatever that this variety is much less affected and less injured by rust in the long run, even though it does not always appear at first. The Argenteuil (Bonvallet's Giant, French and other trade names) is, if not identical with Palmetto, indistinguishable from it, and equally rust proof. Among all the American varieties no great difference exists, and they are in fact probably all selections from the old Conover's Colossal. All the older California fields were of this variety, but by a long succession of generations, taking seed from the old beds to plant new ones, variations have come in and multiplied, until now the fields at Sacramento and Milpitas contain numberless varieties or forms, varying in color from white, through shades of green, yellow, and red, to deep greens and purples, and also varying in size and shape. Most of it has the general Conover characteristics of uniform-sized stalks, tender texture, good flavor, and easy blanching qualities, and the Palmetto type is very little seen, though typical Barr's Mammoth, Columbian White, and almost any other variety can be easily found. The last two varieties named together with Moore's Cross Bred, Donald's Elmira, and the host of various seedsmen's "Mammoth," "Colossal," and "Giant" varieties are probably all selections from the Conover. The canners are opposed to Palmetto on account of its color and coarseness, and the Conover is certainly a much superior canning variety. For marketing fresh asparagus, Palmetto is as good or better, having larger stalks, though less production and poorer quality.

In a rusty field of any variety plants can be seen here and there which are greener, less affected, and more nearly rust proof than the average of the field. A beginning has been made by the writer toward breeding desirable rust-proof varieties by saving seed of such plants from various States, which is being carefully planted for such a purpose. Quite a collection is already on hand from promising sources. Seed has also been imported from Europe of a number of varieties grown there and plants have been obtained from all of these. Variety names, however, outside of the few standard kinds, mean very little in asparagus, as there are many duplicates or kinds indistinguishable from one another. The canning requirements have most to be considered in this State, together with productiveness, as well as rust relation. The Conover is at present the best and only desirable canning variety, and may be grown, it is believed, by thorough methods of rust suppression, but a more resistant kind of equal quality would be extremely desirable and is by no means impossible.

Circular No. 9 contains further remarks on the various varieties.

INSECTS AFFECTING THE ASPARAGUS PLANT.

In connection with the consideration of asparagus rust brief mention must be made of insect pests which attack the same plant, inasmuch as their effects may be confused with those of the rust.

Asparagus Beetle.—This is a small, lively beetle, about one-quarter inch in length, which is getting quite abundant in California and may be expected to increase and become a serious pest within a few years. It seems to have arrived in the State at about the same time as the rust, or at any rate was not noticed by the growers until then. The species is probably identical with the usual *Crioceris asparagi* L., although seeming to vary somewhat from the Eastern form. Specimens have not as yet been submitted to the Entomological division of the Station for determination. The attacks of this insect are most frequently seen on seed-beds and young fields, where both the adult beetles and the grubs, or young form, feed on the shoots as they come up, and cause serious damage. Fig. 46 shows the beetles, grubs or larvæ, and eggs, and the effect on the asparagus.

FIG. 46. Asparagus beetle *Crioceris asparagi*. Chittenden, U. S. D. A. Year Book, 1896.

The grubs may be controlled by dusting with air-slaked lime when the dew is on, while both stages succumb to paris green, mixed with lime, flour, or water. Growers should be on the watch for this insect, as it is quite likely to become troublesome and abundant in California.

Asparagus Miner (*Agromyza simplex* Loew).—This is another Eastern asparagus insect which is becoming abundant in California, though not of any great importance. Its effects are seen at the base of the mature stalks, near the ground, where the very small grubs burrow a broad, winding passage just beneath the epidermis, giving it a slightly sunken appearance. In these burrows may be seen

through the epidermis near the base of the stalk, small, black, seed-like bodies, which are the puparia or winter stage of the insect. From these emerges in spring the adult insect, a small fly. The miner is quite common in this State, but causes no appreciable damage. (Sirrine[1] has called attention to this insect.)

The Onion Thrips.—This very minute insect, which produces the whitened, blasted appearance on green onion stalks, has been observed attacking young asparagus plants in a similar way quite severely where onions were grown between the rows. Should this commonly occur, the planting of this crop in young asparagus fields should be discouraged. The writer has observed thus far but one case of this kind.

Wireworms.—Fig. 31, on page 44, shows an effect quite often seen on asparagus in this State, the work of young *wireworms.* These are very small, lively worms, about one-eighth inch long and hair-like in thickness, which live in the soil, especially when moist and undisturbed. They attack the tender asparagus shoots, eating out "shot-holes" in the sides and making them tough, unsightly, and worthless. These worms are especially troublesome where stable manure has been used in the row, and for this reason some growers have been obliged to abandon the use of such material. In other cases they occur where the ground is wet and soggy.

A remedy for this trouble is found in avoiding or improving the conditions which favor it. The Sacramento practice of plowing down the ridges in winter and putting on a layer of river sand keeps the ground sweet and free from these worms, as well as renewing the soil. When the effects are seen during the cutting season the rows should be pulled down as much as possible with rakes or hooks, a dressing of air-slaked lime sprinkled on the surface, and the ground kept as dry as possible by frequent stirring.

LIST OF SUBSCRIBERS TO FUND FOR ASPARAGUS RUST INVESTIGATION.

California Fruit Canners' Association, San Francisco.
Hickmott Asparagus Canning Company, San Francisco.
Golden State Asparagus Company, San Francisco.
Wm. Boots Estate, Milpitas.
R. S. Barber, Milpitas.
George Murphy, Milpitas.
Henry Abel, Milpitas.
Richards Bros., Milpitas.
M. Bellew, Milpitas.
M. A. Farney, Alviso.
J. W. Meads, Alviso.
Geo. Nicholson, Alviso.
W. Zanker, Alviso.
Fred Cottle, San José.
John I. O'Toole, San José.
Andrea Malavos Co., San José.
R. D. Fox, San José.
F. H. Burke, San José.
F. Gubbay, San José.
Richard Haley, San José.
Bruce Brackett, San José.
L. Scatena & Co., San Francisco.
Jacobs & Malcolm, San Francisco.

[1]Bulletin 189, N. Y. Expt. Sta.

LIST OF SUBSCRIBERS TO FUND FOR ASPARAGUS RUST INVESTIGATION—Cont'd.

Trobock & Bergen, San Francisco.
American Produce Co., San Francisco.
Minaker & Welbanks, San Francisco.
McDonough & Runyon, San Francisco.
A. Galli Fruit Co., San Francisco.
Eveleth Nash Co., San Francisco.
Gray & Barbieri Co., San Francisco.
A. Levy & Co., San Francisco.
John Demartini, San Francisco.
Quadros, Corries & Smith, San Francisco.
Growers' Coöperative Agency, San Francisco.
Goetjen & Metsen, San Francisco.
Meek Estate, Haywards.
G. Oulton, Twitchell Island.
Voorman Estate, Bouldin Island.
P. J. Van Löben Sels, Vorden.
Jacob Olsen, Sacramento.
E. Rider, Sacramento.
M. M. Harding, Sacramento.
O'Brien Bros., Sacramento.
Giusto & Son, Sacramento.
E. Condrey, Sacramento.
C. Girolami, Sacramento.
C. Lagarmarsino, Sacramento.

DIRECTIONS FOR ASPARAGUS RUST CONTROL.

Consider location, soil, and manner of planting in relation to rust, in planting new fields.

Plant Conover's Colossal for canning, Palmetto for the fresh asparagus market.

Cultivate, irrigate if necessary, and in every way take the best possible care of all beds throughout the year.

Allow no asparagus to run wild, and destroy, or at least keep cut down up to July 1, all wild growth.

Apply the same rule to abandoned fields.

Cut and burn all tops in the fall. In young beds not cut for market cultivate or stir the soil as much as possible after cutting the tops, and in early spring. Do not let the new growth come up through surface soil undisturbed since fall.

In sections where rust starts early (Milpitas, Sacramento, etc.) apply from 150 to 200 pounds of sulfur per acre about three weeks after cutting stops, before any rust shows. Put it on in the most convenient way of those described, but with the greatest attention to thoroughness and proper results.

Sulfur only in the early morning, stopping not later than 9 A. M., and choose only mornings when heavy dew is present. The sulfur must show on the tops wherever it is to prevent rust.

If thought preferable, spray the tops with liquid and dry sulfur for very thorough work. If Bordeaux mixture is used in wetting the tops for sulfuring, add soap to the mixture as explained in this bulletin.

About the middle of August give a second application as before, or with 100 pounds of sulfur per acre.

In regions where rust holds off until September or October (Vorden, Grand Island, Andrus Island, etc.) pay strictest attention to the cultural methods of treatment described.

If further treatment seems necessary, spray once about the first week of September with power outfits, using the liquid sulfur formula as given on page 77, prepared as on page 88.

If young beds become rusty before July 1 in spite of cultural methods, cut and burn all the tops and stir the ground thoroughly about two weeks before the old fields stop cutting.

Treatment after the rust appears will do little good anywhere.

NOTE.—Since the announcement of the forthcoming appearance of this bulletin, numerous inquiries have been received from various parts of the country in regard to the application in Eastern States of the methods found successful in California. It should be understood that most of what is said in this bulletin applies only to California conditions, with no rainfall in ordinary seasons from May to October. The use of the liquid sulfur spray suggests itself as being most promising for Eastern application, spraying about three times in the season, the first early in July and the others at intervals of three weeks. An outfit like that in Fig. 41 would be sufficient in most Eastern fields, or power sprayers may be employed. Dry sulfur can not be expected to show much effect in any but a rainless climate.

STATION PUBLICATIONS AVAILABLE FOR DISTRIBUTION.

REPORTS.

1896. Report of the Viticultural Work during the seasons 1887-93, with data regarding the Vintages of 1894-95.
1897. Resistant Vines, their Selection, Adaptation, and Grafting. Appendix to Viticultural Report for 1896.
1898. Partial Report of Work of Agricultural Experiment Station for the years 1895-96 and 1896-97.
1900. Report of the Agricultural Experiment Station for the year 1897-98.
1902. Report of the Agricultural Experiment Station for 1898-1901.
1903. Report of the Agricultural Experiment Station for 1901-1903.
1904. Twenty-second Report of Agricultural Experiment Station, 1903-1904.

BULLETINS.

Reprint. Endurance of Drought in Soils of the Arid Region.
No. 129. Report of the Condition of Olive Culture in California.
131. The Phylloxera of the Vine.
132. Feeding of Farm Animals.
133. Tolerance of Alkali by Various Cultures.
135. The Potato-Worm in California.
137. Pickling Ripe and Green Olives.
138. Citrus Fruit Culture.
139. Orange and Lemon Rot.
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158. California Olive Oil; its Manufacture.
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